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(E75-10120) PREDICT EPHEMERAL AND PERENNIAL RANGE QUANTITY AND QUALITY DURING NORMAL GRAZING SEASON Final Report, 1 Jul. 1972 - 30 Jun. 1973 (Bureau of Land Management, Denver, Colo.) 87 p HC $4.75 CSCL 08F G3/43 N75-16041 Unclas 00120

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PREDICT EPHEMERAL AND PERENNIAL RANGE
QUANTITY AND QUALITY DURING NORMAL
GRAZING SEASON

R. Gordon Bentley, Jr.
Bureau of Land Management

Original photography may be purchased from
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

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16. Abstract

Collection and update of resource inventory data has historically been a difficult, time consuming task. Accurate resource data is necessary as a basis for wise management decisions made by a resource management agency such as the Bureau of Land Management. Black and white and color infrared composites of ERTS satellite imagery at 1:1,000,000 and enlarged scales can be used as data gathering tools. No investment in expensive sophisticated equipment is necessary. A photo interpreter can map boundaries of soils, plant communities, levels of forage production, areas revegetated by man and areas burned by wildfire directly from satellite imagery. The ERTS system of producing and distributing imagery must be improved greatly before satellite imagery can be useful to the resource manager.

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LIST OF TABLES

I. INTRODUCTION

The United States Department of the Interior, Bureau of Land Management (BLM) administers the resources of approximately 470 million acres of public domain lands in the 11 western states and Alaska. Funds and manpower are becoming more and more limited as costs rise and additional tasks are required by a public demanding increased services and a higher quality environment. Historically, resource data necessary for management decisions has been collected on the ground by a resource specialist who arrived at a specific site by pickup truck, jeep, horse, or sometimes even on foot. Aircraft photography is used, where available, but often photos are several years old and may not truly reflect current conditions.

As the world moves into the computer age, it is important that resource management adopt new tools and techniques which will enable managers to quickly collect initial information, and at the same time, be able to just as easily update that information on a regular schedule. Information collected from a dynamic ecosystem is only accurate for the instant during which it was observed.

Carneggie (1968) states that most of the world's rangelands are not producing food and fiber equal to their potential and that this is "due in part to misuse or mismanagement of the range resource stemming from a general lack of knowledge concerning the ecology of ranges. . ." He agrees that improved methods of inventorying range resources are needed. Krumpe (1973) has shown that vegetation can be mapped from ERTS color composite satellite imagery on a regional basis.

Resources used by the public on lands administered by BLM are many and varied, as are the management situations and problems they create. In the desert regions of California, Arizona, and New Mexico, management of livestock grazing requires close attention to climate and its effects on fast growing ephemeral vegetation. Livestock operations in the desert are highly seasonal depending upon a combination of adequate precipitation and moderate winter temperatures. Such a condition generally occurs not more than two or three years out of 10. For this reason, livestock operations are highly speculative. During good years a given site may produce ephemeral forage at a rate of several thousand pounds per acre, while in a poor year the same site may produce little or nothing.

Availability of livestock and prices are keyed to ephemeral forage production. Since forage conditions are highly variable, livestock operators often do not own cattle on a yearlong basis. Livestock operators may go several years without grazing cattle on the range. When forage conditions are favorable, cattle are purchased with the intent of fattening or maturing them on the range. Many of the cattle grazed in this way are raised in Mexico and may be six months to two years old at the time they enter the United States. When it is evident that forage is developing in the United States the price of cattle in Mexico rises. As good forage production becomes assured, the price of cattle greatly increases.

Forage production is extremely difficult to predict. Climatic conditions can change rapidly and the proper combination needed to produce adequate quantities of ephemerals may occur at any time during the growing season and may last for an indefinite period. The livestock operator who guesses right can make a substantial profit, the one who guesses wrong can go broke. The operator who waits too long for forage conditions to "prove-out" must buy expensive cattle and may face a short grazing period.

BLM needs a means of monitoring forage conditions on vast areas of the southwestern desert. BLM now tries to manage the grazing resource with one range conservationist for every 700,000 acres. Under these conditions it is extremely difficult to do an adequate job. When a range conservationist now inspects his area of responsibility to determine forage conditions, he drives through a representative portion and makes occular estimates. His course is based upon road location and condition, habit, and personal biases. He then extrapolates this information from sample areas to other representative areas in the same general region. Success in extrapolating information is variable. A tool is needed which will allow the range conservationist to thoroughly study every part of his area of responsibility.

In California tremendous pressures are being placed on the land by vast numbers of people leaving the large metropolitan areas on weekends and during vacations, seeking recreation and relief from tensions created by urban life. Four-wheel drive vehicles and motorcycles are driven over every conceivable kind of terrain in the name of recreation. Campers by the thousands may stay in one spot for several days trampling the area into a dust bowl.

For years BLM has recognized the danger of using the fragile desert ecosystem to such intensities, but little data exists to substantiate this awareness. BLM administers some 16 million acres of desert in California with a relatively small force. A tool is needed which will help BLM inventory soils and vegetation quickly and simply. Initially data can be obtained on a regional basis with greater detail built upon this basic pool of knowledge in specific areas where people pressures are greatest or resource values are in danger of being destroyed.

The western livestock industry, such as found in Oregon, is built upon a foundation of public owned grazing lands. The bulk of these lands produce perennial forage. BLM has instituted a program for management of these lands which would perpetuate and improve condition of perennial plants while at the same time harvesting the forage they produce, BLM (1968). Administering these grazing systems is a task which requires the range manager to pay close attention to the growth, development, and health of the vegetation. Manpower is limited. A tool is needed which would aid the manager in gathering resource data accurately and on a periodic basis.

In Alaska the Bureau of Land Management administers approximately 300 million acres of virgin land. Very little information has been obtained about vegetation in Alaska. A tool is needed to aid BLM in mapping vegetation on a regional basis.

II. PROBLEMS ENCOUNTERED IN THE STUDY

During the course of this study, several problems were encountered which are peculiar to the use of satellite imagery. These problems and their solutions are reported in the hope that they may assist persons using satellite imagery in the future. At the beginning of the study two areas were selected in Arizona for detailed analysis. Based on information from NASA, it was realized that no item on the ground smaller than 300 feet would probably be distinguishable (resolution). Therefore, study sites were made purposely larger than normal; 200 square miles and 25 square miles in size.

Each site was stratified into distinct vegetative communities using aerial photographs and ground truth data. Detailed plant measurements were made on each vegetative type including percent ground cover and forage production. When the first ERTS frames were received, it was evident that the study sites were too small. The 25 square mile site was a part of one larger homogeneous tone which could be distinguished on the satellite image. The smaller areas within the site that had been stratified on the ground could not be separated on the ERTS frame. As a result of this lack of detail, the entire ERTS frame was used as a study site. Vegetative measurements on small areas were changed to occular estimates over much larger regions.

Obtaining usable imagery has been a very difficult task. BLM as a management agency does not own equipment suited to research; in this case, a color additive viewer. Access to a color additive viewer required airplane travel and per diem, making use of such a machine very costly. In addition, results obtained from producing color composites by this means have been discouraging. Resolution of images produced on the I^2S viewer used for this study was only fair. Interpretation of imagery could only be done in the office; color composites could not be taken to the field. Photographs of the color image seen on the viewing screen produced images of poor quality.

An attempt was made to produce color composite images from 9x9 inch positive transparencies by means of exposing yellow, magenta, and cyan diazochrome film with light projected through positive transparencies in MSS bands 4, 5, and 7, Bowden and Johnson (1972). This procedure was rather slow and good registration of the separate bands sandwiched together was difficult to maintain. Separate sheets of film tend to slip out of registration or change shape causing a loss of registration. Images thus produced could only be analyzed by viewing them through a light table. The images could be photographed with fair success but this creates an additional step which must be completed.

A useable simulated color infrared image was finally obtained without too much trouble through the use of a triple-exposure camera technique first obtained from Belon (1972). Light from several 3200°K 500 watt lamps is used to illuminate 9x9 inch positive transparencies of ERTS imagery in MSS bands 4, 5, and 7, see Figure 1. All three transparencies are registered in exactly the same spot on the light table and a sheet of seven mil thick stable base mylar of equal size is placed over the transparencies. This four layer sandwich is taped together so no lateral movement can occur. A precision one-quarter inch one-hole hand punch is then used to punch holes simultaneiously in the four corners of the mylar and three positive transparencies. Plastic map registration buttons, one-quarter inch diameter (Figure 1) are put in the four holes of the mylar sheet and taped permanently in place. A parallelogram shaped window exactly conforming to the satellite image area is cut in the mylar leaving a border or template holding the registration buttons. This mylar registration guide is taped to the light table in turn and photographed separately to produce a composite image without losing registration.

A Nikon F2 35 mm slide camera was used because it is capable of making multiple exposures accurate to one thousandth of an inch. A 55 mm MICRO-NIKKOR close up lens was used to obtain the greatest possible image sharpness. An 80A filter was used to maintain color balance. Kodacolor-X (CX-135-20) color print film was used to produce 8x10 color photographs. All three positive transparencies are photographed on the same negative (the camera shutter is cocked each time but the film is not advanced). Each transparency (Figure 1) is photographed through a different filter:

MSS band 4	Wratten filter No. 47
MSS band 5	Wratten filter No. 58
MSS band 7	Wratten filter No. 29

The procedure described above can also be followed with a copy camera using 2 1/4 x 2 1/4 inch or 4x5 inch film, resulting in improved image quality. However, such a camera was not available, neither was the extremely heavy camera stand such equipment would require. Eastman Kodak (1970) gives plans for constructing a copy stand out of lumber which proved adequate for use with the Nikon camera.

Proper color balance on photographic prints of simulated color infrared composites is extremely difficult to obtain from commercial processing labs. Most lab technicians are trained to balance for facial tones, clothing, or green vegetation and common flowers. They become very bewildered when they are confronted with the complex mixture of hues found in satellite images, such as shown in Figures 6 and 14b. The only real solution is to do your own color processing. Unfortunately, this is often not possible. The next best alternative is to work with a local custom lab where people are willing to take the time to experiment. This can be expensive. A proof sheet can be helpful, especially when several different satellite images are photographed on a single roll of film. Color balance is more true on the proof sheet and serves as a guide for 8x8 inch enlargements. Another problem is scale of photographs. Unless specified, images will come from the processor in a variety of sizes.

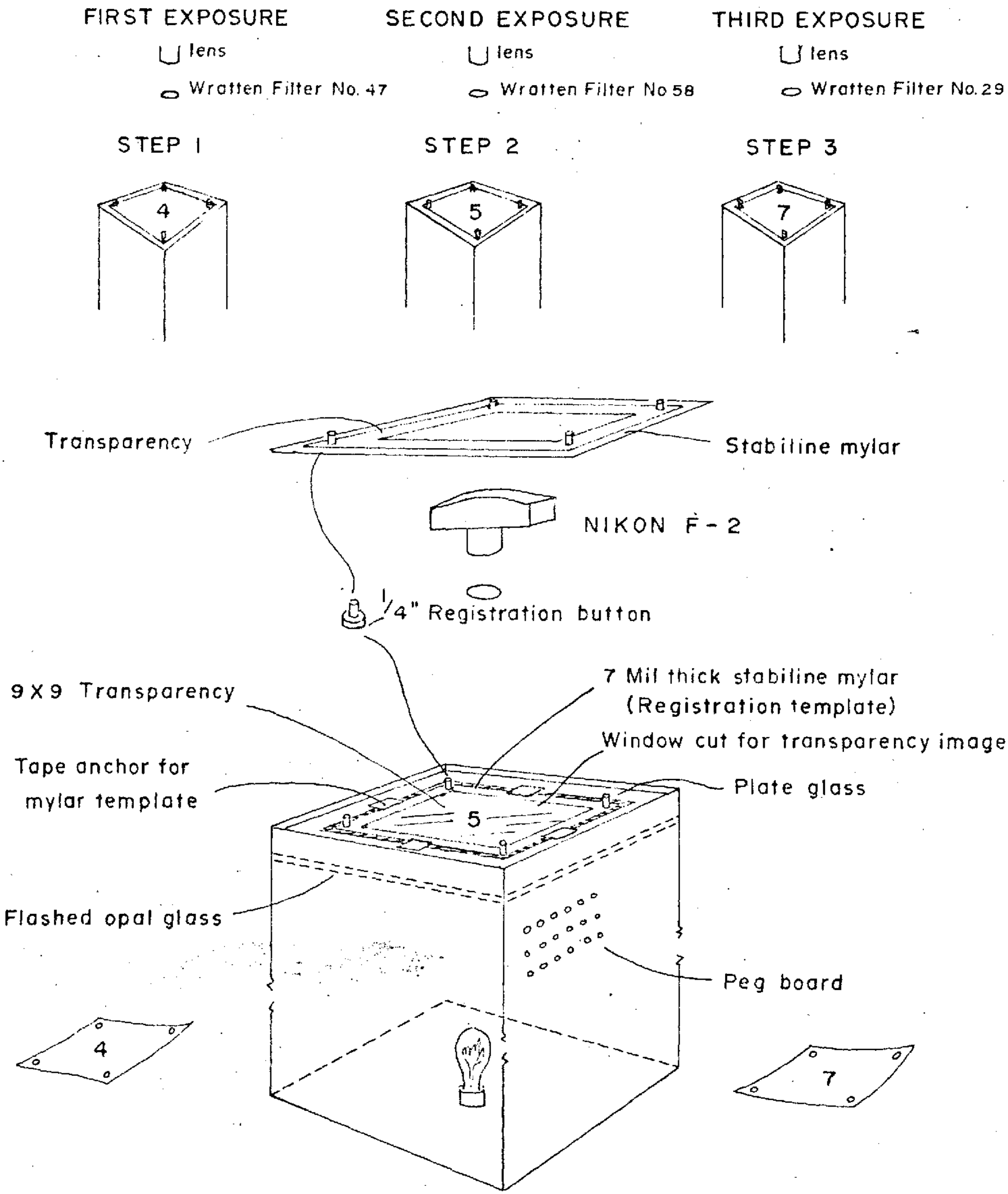

FIGURE 1. Equipment needed for the triple-exposure camera technique and step-by-step procedure.

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III. DISCUSSION OF STUDIES CARRIED OUT ON EACH OF FOUR SITES AND RESULTS OBTAINED

A. Arizona Sites

1. Site Description

Two general areas were selected for study, representing the high desert and the low desert, see Figure 2. The high desert site was located in the southeastern corner of Arizona, around the town of Safford. The low desert site was located approximately in south central Arizona, with Phoenix in the northwest corner and Tucson near the southeast corner of the study area.

2. Objectives

Utilize satellite imagery to:

a. Determine the amount of ephemeral forage produced on specific sites with a precise boundary between sites.

b. Monitor change in growth and development of ephemeral plants. This relates to range readiness, when plants can properly be grazed.

c. Determine if forage production can be predicted several weeks in advance.

d. Be able to separate sites according to potential productivity.

3. Study Method

a. Climate

Weather stations were located ten miles south Safford and 33 miles northwest of Tucson on the north slope of the Silver Bell Mountains. The following weather data was collected:

(i) Precipitation
(ii) Temperature
(iii) Wind movement

Precipitation records for other weather stations in the general area were also analyzed.

b. Vegetation Measurements

The following information was collected by visual estimates. Production estimates were checked periodically by clipping and weighing sample plots.

FIGURE 2. Map showing the Arizona test sites.

(i) Stage of plant growth
(ii) Height of plant growth
(iii) Ephemeral forage production by site
(iv) Oblique photographs of representative sites

Initial measurements were made on the small original test sites located prior to launch of the satellite. In February observations were expanded over the area covered by an ERTS frame after analysis of imagery showed that the 1:1,000,000 scale was too small to show detail of existing sites. Analysis of imagery pointed out different sites and ground truth measurements were made within these distinct areas. Aerial reconnaissance by light aircraft aided further in the proper selection of sites. During reconnaissance flights, color infrared photographs were also taken using a hand-held 35 mm camera loaded with IE-135-20 film. Photos were taken of different vegetative communities for further reference to hue, tones, and textures observed on ERTS imagery.

c. Analysis of Imagery

Color infrared satellite imagery at a scale of 1:1,000,000 was analyzed visually by an interpreter using no special equipment. Overlay material was placed on the color print and information recorded with a sharp pointed nylon tipped marking pen having ink which would adhere to smooth acetate. Boundaries were drawn around homogeneous areas, those having the same hue, tone and texture. The initial analysis was then verified in the field using ground truth data. Reconnaissance flights were also made to further check boundaries. With satellite imagery and overlay material in hand, the interpreter made necessary corrections as he flew over the test site, a system used effectively by David Carneggie (1972).

4. Results and Discussion

Usable imagery was received for the following dates:

Phoenix - Tucson Site

E-1085-17330*	16 Oct. 72
E-1103-17332*	03 Nov. 72
E-1193-17333	01 Feb. 73
E-1211-17334	19 Feb. 73

Safford Site

E-1083-17215*	14 Oct. 72
E-1245-17222 and 17225	25 Mar. 73
E-1263-17222 and 17225	12 Apr. 73
E-1299-17223	18 May 73

*NOTE: Frames purchased from the Sioux Falls Data Center (purchased as 9x9 inch positive transparencies in MSS bands 4, 5, 6).

Additional imagery received was not useful because of cloud cover. As sufficient usable imagery was not received during the growing period, no attempt was made to predict forage production from satellite data. Monitoring changes in plant growth and development was difficult for the same reason, but the four images on the Phoenix-Tucson site do indicate that changes in plant growth can be seen if percent ground cover is great enough.

Imagery received during the summer and fall seasons for the Arizona desert sites was of very poor quality. Because of the high sun angle during summer, incidence of light stricking the earth's surface is very great. A high percentage of this light is reflected from desert soils, especially those on valley floors, because soils are light colored and vegetation is very sparse. The result is a washed out image, one with rather low density differences between areas of normally high contrast. Imagery obtained from the Sioux Falls product is at lease one generation degraded from imagery sent by NASA.

High flight imagery flown by the U-2 aircraft was received for several dates. The imagery was of very limited use to this study for several reasons. Much of the imagery received was in the form of 70 mm multiband imagery taken with the Vinten camera system. The multiband images were combined into color infrared composites on the I^2S color additive viewer. Figure 3 illustrates a sample image taken over the Silver Bell Mountains and Santa Cruz River. The image lacks sharpness and detail because of grainy positive transparencies, and difficulty in obtaining true registration with the I^2S viewer. Also, little information about desert vegetation is visible since the photo was not taken during the growing season.

Color infrared imagery taken with the RC-8 camera from several NASA U-2 flights was also received. Imagery from two flights was very blue yielding little information. Imagery from Flight No. 72-129 taken on August 1, 1972 with the RC-8 camera, Accession No. 00560, was of excellent qaulity. However, it was not taken during the growing season. This imagery was of some use to show how different soil types are depicted in color infrared.

a. Phoenix - Tucson Site

By comparing satellite imagery taken in the fall (Figure 4) prior to initiation of ephemeral plant growth and soon after growth began (Figure 5) with satellite imagery taken at the peak of the growing period (Figure 6), the interpreter was able to distinguish different amounts of forage produced on several different sites. Sites supporting a mixture of perennial trees and shrubs were easily distinguishable from sites supporting predominately <u>Larrea tridentata</u> -- creosotebush. For a list of species, see Table 1. The tree-shrub sites were located on the upper

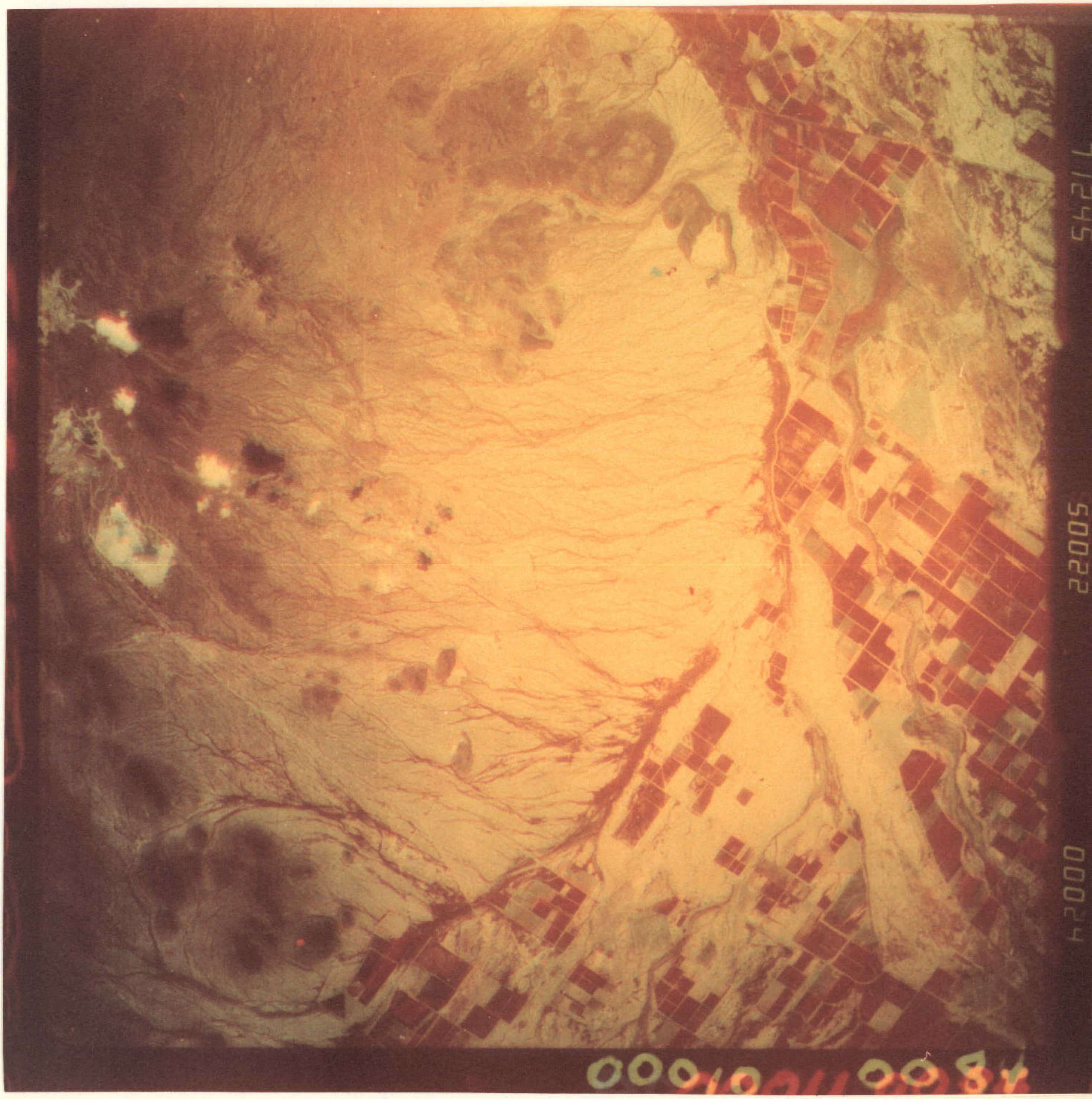

FIGURE 3. Color infrared composite image made from 70 mm positive transparencies in the green, red and infrared bands. Imagery was produced by the Vinten camera system aboard NASA U-2 aircraft flown at an altitude of approximately 65,000 feet. Flight No. 71-026, date 9/2/71. Area of coverage is the Red Rocks-Silver Bell Mountains area on the Phoenix-Tucson test site.
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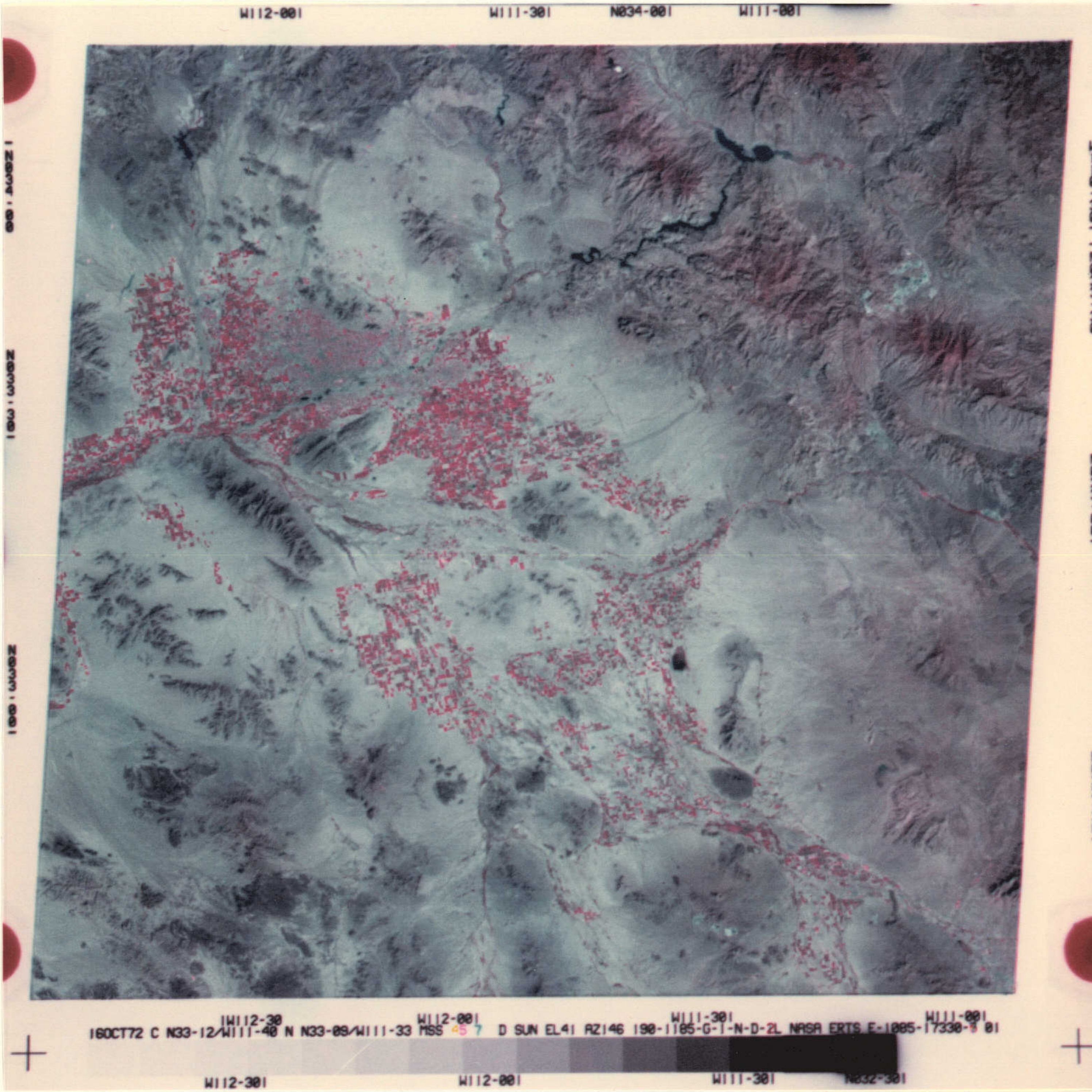

FIGURE 4. Simulated color infrared composite image of ERTS frame 1085-17330, 16 Oct. 72; approximately 1:1,000,000 scale for the Phoenix-Tucson test site. (EDC- 010032)

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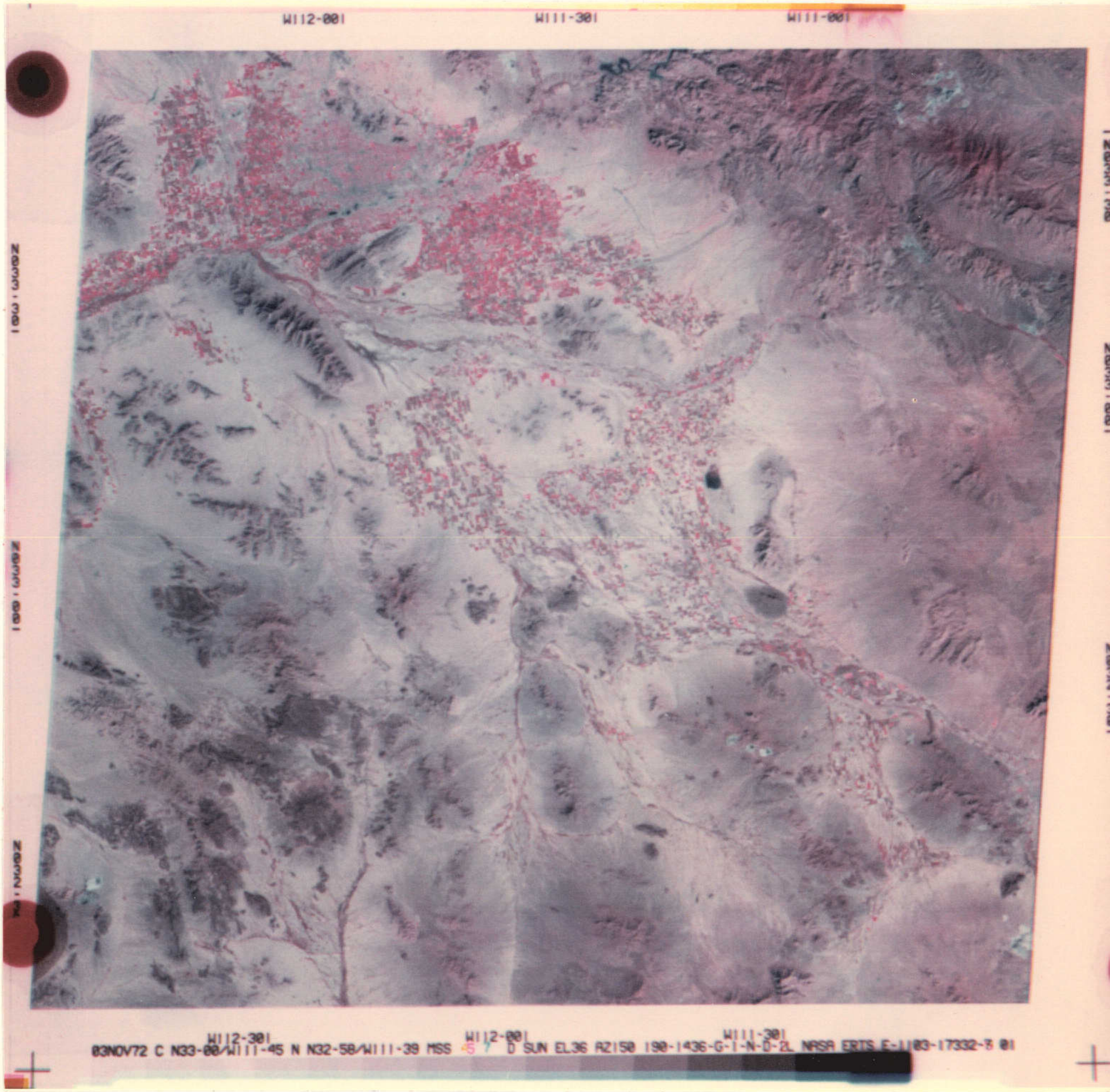

FIGURE 5. Color composite image of ERTS frame 1103-17332, 03 Nov. 72; approximately 1:1,000,000 scale for the Phoenix-Tucson test site. (EDC-010038)

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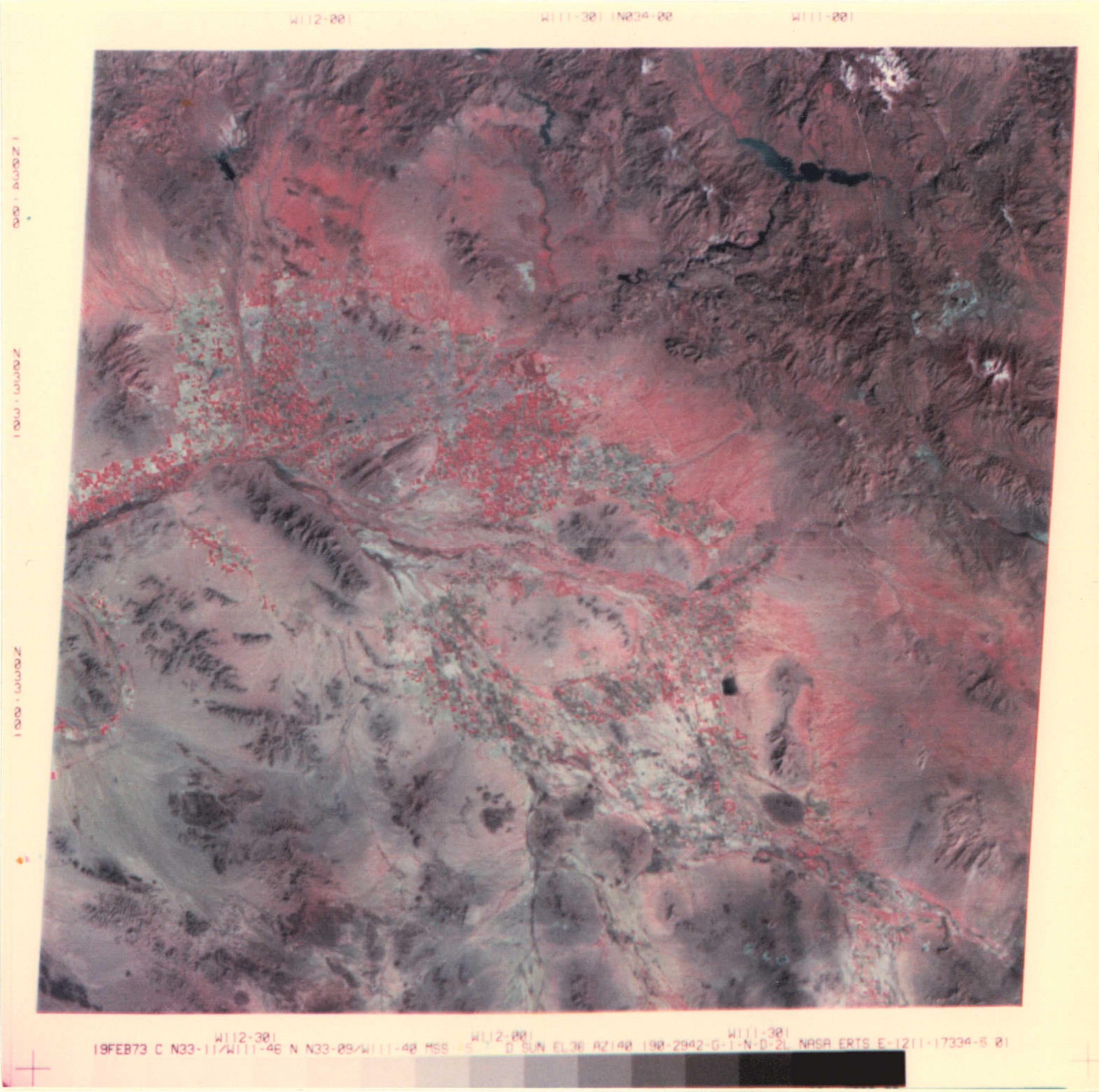

FIGURE 6. Color composite image of ERTS frame 1211-17334, 19 Feb. 73; approximately 1:1,000,000 scale for the Phoenix-Tucson test site. (EDC-010039)

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TABLE 1. List of perennial and ephemeral plants found on tree-shrub sites and creosotebush sites in Central Arizona

Tree-Shrub Sites	Creosotebush Sites
Perennial Plants	**Perennial Plants**
Cercidium floridum - paloverde	*Larrea tridentata* - creosotebush
Olneya tesota - ironwood	
Prosopis juliflora - mesquite	
Carnegiea gigantea - saguaro	
Baccharis sarothroides - broom baccharis	
Larrea tridentata - creosotebush	
Franseria dumosa - white bursage	
Encelia farinosa - brittlebush	
Hymenoclea salsola - burrobrush	
Acacia greggii - catclaw	
Yucca spp. - yucca	
Opuntia spp. - cholla	
Annual Plants	**Annual Plants**
Festuca octoflora - sixweeks fescue	*Erodium cicutarium* - filaree
Phacelia crenulata - wild-heliotrope	*Plantago purshii* - indian-wheat
Amsinckia intermedia - fiddleneck	*Phacelia crenulata* - wild-heliotrope
Plantago purshii - indian-wheat	*Amsinckia intermedia* - fiddleneck
Erodium cicutarium - filaree	
Eriogonum densum - buckwheat	
Nemacladus glanduliferus - threadplant	
Orthocarpus purpurascens - escobita	
Descurainia pinnata - tansy-mustard	
Astragalus nuttalianus - milkvetch	
Lupinus sparsiflorus - lupine	
Sphaeralcea coulteri - globemallow	

portion of outwash plains and low hills at the base of desert mountains. The creosotebush sites were on the lower portion of outwash plains and on valley floors.

The tree-shrub sites produced a very good mixture of emphemeral plant species during the winter-spring growing season, while the creosotebush sites produced a small number of ephemeral species, usually with only one species being dominant on an area, see Table 1. Several levels of ephemeral forage production on both the tree-shrub (perennial-ephemeral sites) and creosotebush (ephemeral sites) sites were also distinguishable on satellite imagery, see Figure 7 and Table 2.

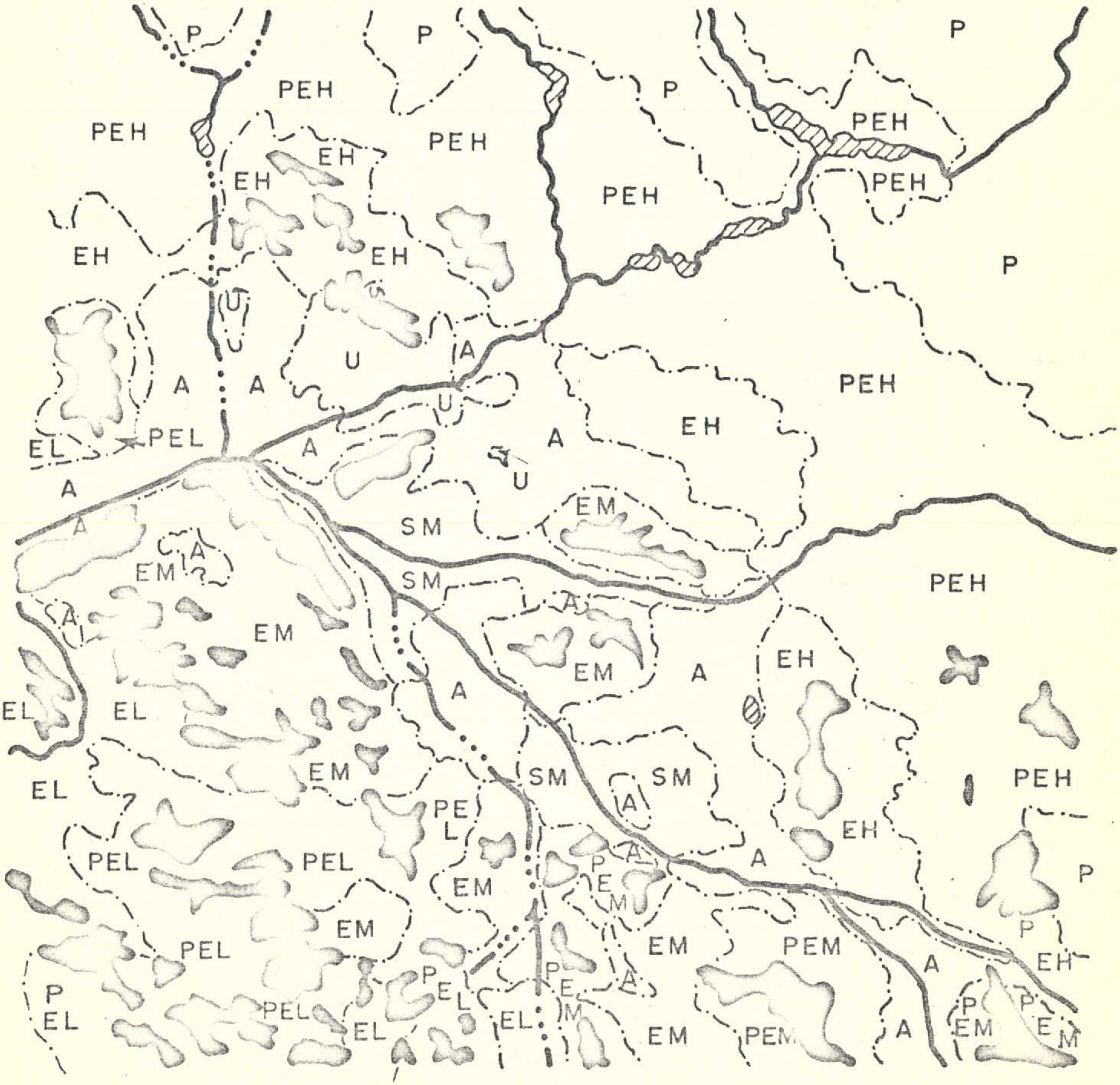
Different vegetative communities were delineated on the basis of hue, tone and texture. Krumpe used color differences and textures to great advantage. However, his color key was much more detailed than the key used in this study, see Table 3. Perennial desert plants apparently reflect very little energy in the near infrared portion of the electromagnetic spectrum. This is clearly shown in Figure 8. The white fingers dotting the color infrared photograph are saguaro cacti. The rounded white spots are paloverde and ironwood trees. The large gray-blue areas in the photo center are stands of white bursage; the small blue areas are rock outcrops. Creosotebush plants are not visible at all. Therefore, desert perennial vegetation does not show red or pink on color infrared even though these plants are actively growing.

During the fall before ephemeral plants begin growth, creosotebush sites appear very light blue on satellite imagery; see Figure 4. The tree-shrub sites appear a darker gray-blue. In winter when ephemeral plants are actively growing, creosotebush sites reflect only the effect ephemerals have on infrared reflectance. The result is a gradation of pink to bright red depending upon the amount of ephemerals present on the site. These areas can be seen in Figure 6 and are also designated as Ephemeral (E) sites in Figure 7.

The tree-shrub sites reflect the effect of scattered ephemerals intermixed with a variety of shrubs which mask the true effect of the ephemerals. The resulting color on satellite imagery is a blue with red spots or streaks where ephemeral production is heavy grading to a pure blue where little ephemeral production occurs. These areas can be seen in Figure 6 and are also designated as Perennial - Ephemeral (PE) sites in Figure 7. Figure 9 illustrates the tree-shrub (PE) site as located in mountainous areas. On satellite imagery these areas exhibit color tones similiar to PE sites elsewhere, but texture patterns are rough rather than smooth.

In collecting ground truth data throughout the central Arizona region, saguaro cactus was found only on the tree-shrub sites. These are the darker gray-blue areas on satellite imagery. No saguaro exists on the light areas designated as predominately creosotebush.

FIGURE 7. Ephemeral forage plant production as determined from ERTS Satellite Imagery, Frame 1211-17334, 19 Feb. 73.



LEGEND

U – Urban Area
A – Agricultural Land
P – Perennial Plants
PE – Perennial – Ephemeral
E – Ephemeral
S – Saltbush
H – Heavy Production
M – Moderate Production
L – Light Production
Rock Outcrop (light production)
Lake

TABLE 2. Ephemeral forage production (air dry weight) for Winter Season 1972-73, as of April 18-19, 1973

Vegetation Type	Production Class	Forage Production lbs./acre
Urban	-----	-----
Agricultural Land	-----	-----
Perennial	-----	-----
Perennial - Ephemeral	Heavy	1000-1500
Perennial - Ephemeral	Moderate	500-1000
Perennial - Ephemeral	Light	up to 500
Saltbush (drainage channels)	Moderate	500-1000
Ephemeral	Heavy	3000-5000
Ephemeral	Moderate	2000-3000
Ephemeral	Light	up to 2000
Perennial - Ephemeral (rock outcrops -- Desert Mtns.)	Light	up to 1000

TABLE 3. Color-texture key used to separate ephemeral forage production classes.

Color	Texture	Vegetation Type	Ephemeral Forage Production Class
Blue with red spots & streaks intermixed	Striated	Perennial-Ephemeral	Heavy
Bluish gray with pink blotches	Striated to smooth	Perennial-Ephemeral	Moderate
Blue	Striated to smooth	Perennial-Ephemeral	Light
Bright red	Mottled to smooth	Ephemeral	Heavy
Pink	Smooth	Ephemeral	Moderate
Light Pink to white	Smooth	Ephemeral	Light
White, dark purple to red	Streaked	Drainage channel	Moderate
Blue to gray	Rough	Desert Mtn.	Light
Red to brownish red	Rough	Perennial	None

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FIGURE 8. Color infrared photo taken with a hand-held 35 mm camera from a light aircraft. Perennial plants reflect little infrared energy and appear as white objects (EDC-010040)

Figure 10 illustrates an example of the large areas covered by drainage channels in central Arizona. These areas appear as white, blue, green, and red streaks in a combined pattern on satellite imagery, reflecting alkaline deposits, bare soil, dormant, and actively growing vegetation, respectively. Production of Ephemeral (creosotebush) and Perennial-Ephemeral (tree-shrub) sites is shown in Figure 7 as heavy (H), moderate (M), and light (L) production classes. Figure 11 shows these three classes of production as found on the Perennial-Ephemeral vegetative site.

A careful examination of Figures 4 and 5 shows that the 03 Nov. 72 image exhibits more color infrared in the PE and E areas in the east central and north central portions of the image. These areas accounted for the heavy forage production during the 1972-73 growing season. The amount of color infrared that can be seen on the November image as compared with the 16 Oct. 72 image is slight, but very significant considering the small amount of ephemerals produced by November 3. A cursory analysis of satellite imagery taken in April and May shows that ephemeral plants drying out at maturity can be monitored. There is a distinct loss of color infrared in this imagery compared with the 01 and 19 Feb. 73 images. These results, while preliminary, do indicate that change in growth and development of ephemeral plants over fairly large areas can be monitored from satellite altitudes. Figure 12 is a series of ground truth photographs charting the phenologic stages of ephemeral plants in the creosotebush type from before seedlings germinate through the drying period after plants have died. This series illustrates the magnitude of changes which can occur as well as the production potential of creosotebush sites.

A tentative potential production map (Figure 13) was drawn using production data correlated with weather data (Tables 4 and 5) and differences in elevation between areas. Data from imagery taken over several years at peak growing period is needed to firmly establish potential production of sites.

b. Safford Site

Contact color infrared composite prints at an approximate scale of 1:1,000,000 of ERTS satellite images 1245 - 17222 and 17225, taken 25 Mar. 73, over the Safford test site were analyzed visually by an interpreter; see Figures 14a and 14b. Different degrees of gradation from pink to red reflect different levels of livestock forage production. The bright yellow areas reflect the presence of substantial stands of Lesquerella gordoni -- bladderpod. Figure 15 shows a tentative potential production map for ephemeral forage drawn from the analysis of satellite imagery.

FIGURE 9. The tree-shrub or Perennial-Ephemeral (PE) vegetative type seen in rugged mountainous areas. Photo taken from light aircraft. (EDC-010041)

FIGURE 10. A section of drainage channel south of Phoenix where the Gila and Santa Cruz Rivers and Santa Rosa wash all come together. Note light colored saline deposits. (EDC-010042)

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FIGURE 11. Ground truth photographs showing three classes of ephemeral production in the Perennial - Ephemeral (PE) vegetative site. Top photo - Heavy production (PEH), LL - Moderate production (PEM), LR - Light production (PEL). Top (EDC-010043)
LL (EDC-010044) LR (EDC-010045)

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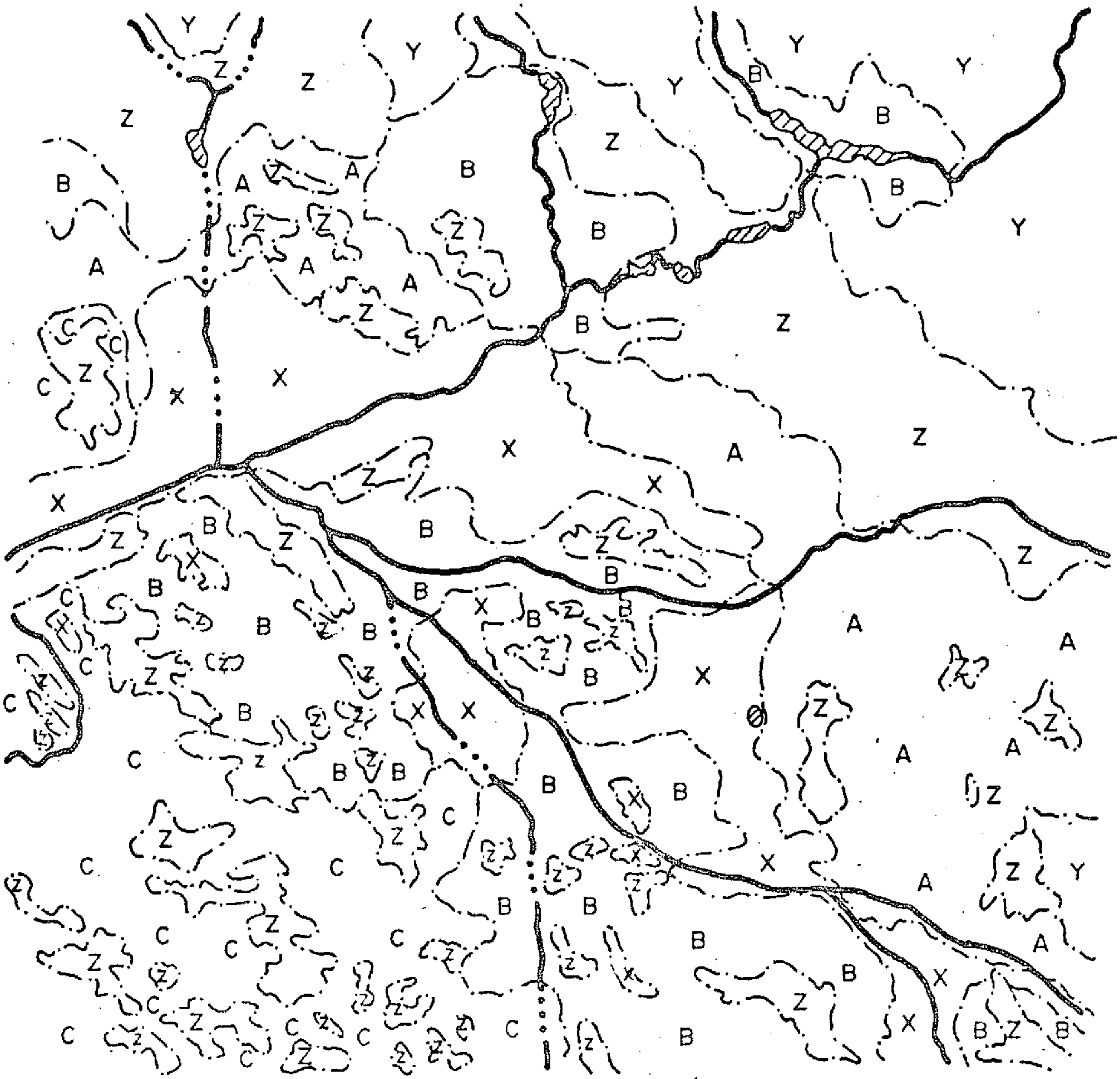
FIGURE 12. Photos depicting plant phenology of ephemerals in the creosotebush type. UL - 9-1-72, UR - 11-28-72, LL - 4-18-73, LR - 5-3-73. UL (EDC-010046) UR (EDC-010047) LL (EDC-010048) LR (EDC-010049)

FIGURE 13. Potential of areas to produce Ephemeral Forage Plants.



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LEGEND

X – No Ephemeral Potential (urban & agriculture)

Y – No Ephemeral Potential (perennial plants)

Z – Low Useable Ephemeral (steep topography)

A – High Ephemeral Potential

B – Moderate Ephemeral Potential

C – Low Ephemeral Potential

TABLE 4. Precipitation data during the 1972-73 winter growing season taken from selected stations in the study areas.

Weather Station	Elev. ft.	MONTHLY PRECIPITATION RECORD IN INCHES 1972 Sep.	Oct.	Nov.	Dec.	1973 Jan.	Feb.	Mar.	Apr.	May	TOTAL
Phoenix-Tucson Site											
Northwest											
Falcon Field	1320	0.07	4.71	1.18	1.89	0.40	2.37	2.35	0.05	0.25	13.27
Central											
Casa Grande	1405	----	3.70	1.75	1.04	0.04	1.80	2.62	----	0.12	11.07
Southwest											
Ajo	1763	0.37	3.24	0.44	0.65	0.04	1.46	1.71	----	0.08	7.99
Santa Rosa Sch.	1840	----	2.76	0.96	NR	----	1.46	1.72	----	T	6.90*
Southeast											
Silver Bell	2740	1.35	5.60	2.96	1.14	0.20	2.76	3.49	0.08	0.32	17.90
BLM Station	2275	0.80	4.15	2.25	0.65	0.15	1.60	3.15	----	0.45	13.20
Oracle	4540	2.15	6.75	2.91	1.93	1.23	4.30	5.55	0.27	0.77	25.86
East											
Florence	1505	0.19	5.75	1.84	1.33	0.27	2.03	2.80	0.10	0.41	14.72
Safford Site											
Northwest											
Safford Expt. Farm	2954	1.83	3.68	0.49	0.40	0.22	2.17	1.47	0.03	0.49	10.78
BLM Station	3320	0.80	2.80	0.37	0.57	0.30	1.95	1.85	0.05	0.35	9.04
Southwest											
Bowie	3770	0.88	4.39	0.87	0.66	0.62	1.27	2.25	0.09	0.35	11.38
Southeast											
San Simon	3880	2.13	2.86	0.34	0.58	0.75	0.84	1.63	----	0.41	9.54
Northeast											
Duncan	3660	0.93	4.40	0.37	0.56	0.64	2.50	1.70	----	0.82	11.92

NR - No Record

*NOTE - Record Not Complete

TABLE 5. Weather data from two BLM stations collected during the 1972-73 winter growing season

MONTH	AVERAGE MONTHLY WEATHER READINGS									
	BLM Silver Bell Station					BLM Safford Station				
	Temperature °F		Wind-Mi./12 hr.		Precip.	Temperature °F		Wind-Mi/12 hr.		Precip.
	Avg. Hi	Avg. Low	0600-1800	1800-0600	inches	Avg. Hi	Avg. Low	0600-1800	1800-0600	inches
Sept.	93.5	67.4	13.1	9.6	0.80	88.2	58.6	20.3	4.8	0.80
Oct.	NR	NR	9.6	8.6	4.15*	72.3	50.9	21.2	7.0	2.80
Nov.	NR	NR	14.2	4.8	2.25*	60.3	32.4	19.8	5.1	0.37
Dec.	61.0	36.0	11.2	7.2	0.65	NR	25.7	20.8	13.6	0.57*
Jan.	61.3	32.8	7.7	12.5	0.15	53.5	27.3	20.5	4.5	0.30
Feb.	65.4	40.5	15.7	7.4	1.60	56.6	32.2	9.0	2.8	1.95
Mar.	64.2	40.5	23.8	10.2	3.15	59.6	34.3	36.2	11.5	1.85
Apr.	78.1	43.6	25.4	10.4	----	71.6	40.2	39.4	13.4	0.05
May	85.0	51.8	23.9	9.8	0.45	86.0	50.7	33.2	10.0	0.35

NR - No Record

*NOTE - Record Not Complete

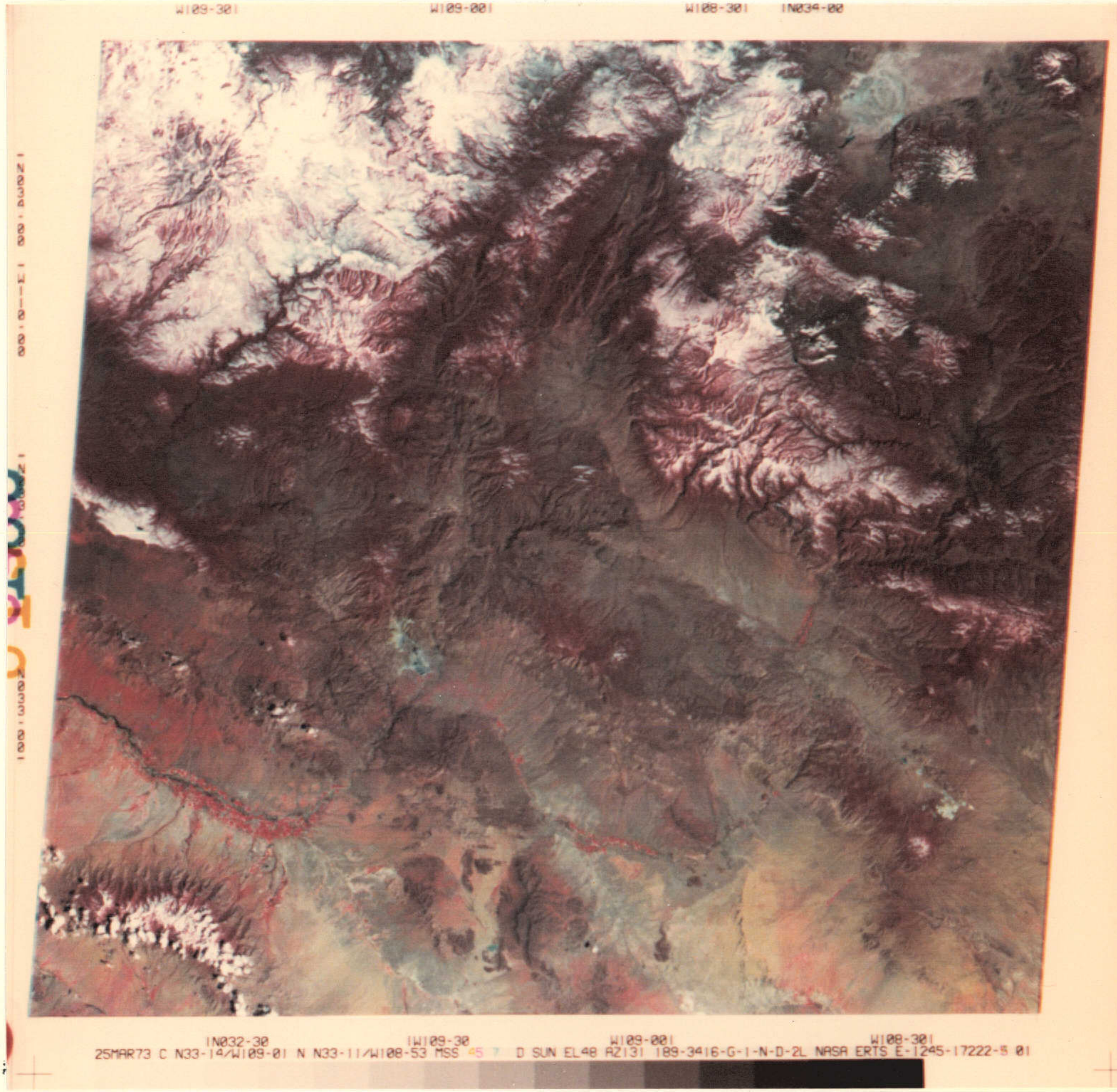

FIGURE 14a. Color composite image of frame 1245-17222, 25 Mar. 73 of the Safford north test site.

(EDC-010050)

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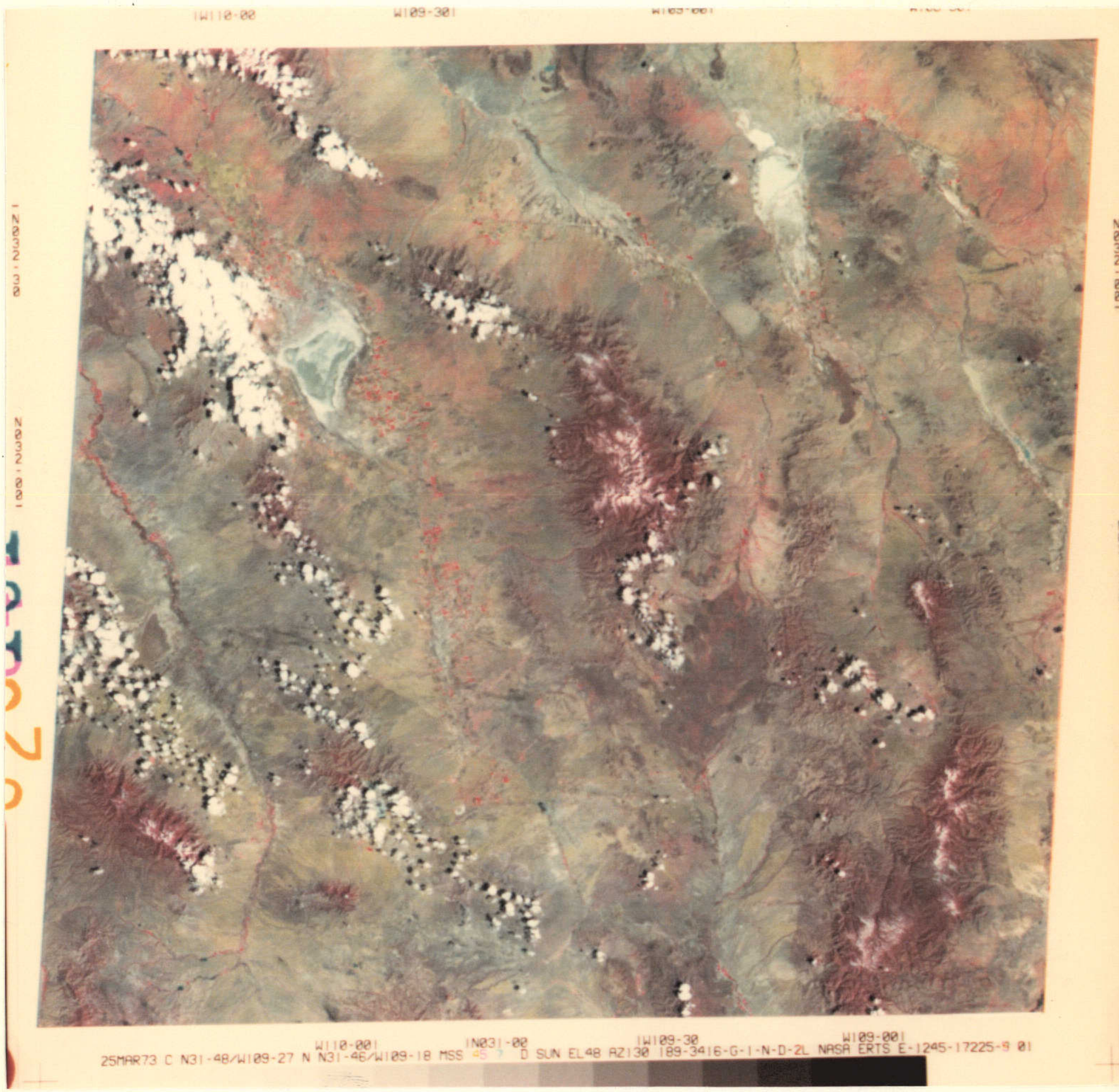

FIGURE 14b. Color composite image of ERTS frame 1245-17225, 25 Mar. 73 of the Safford south test site.

(EDC - 010051)

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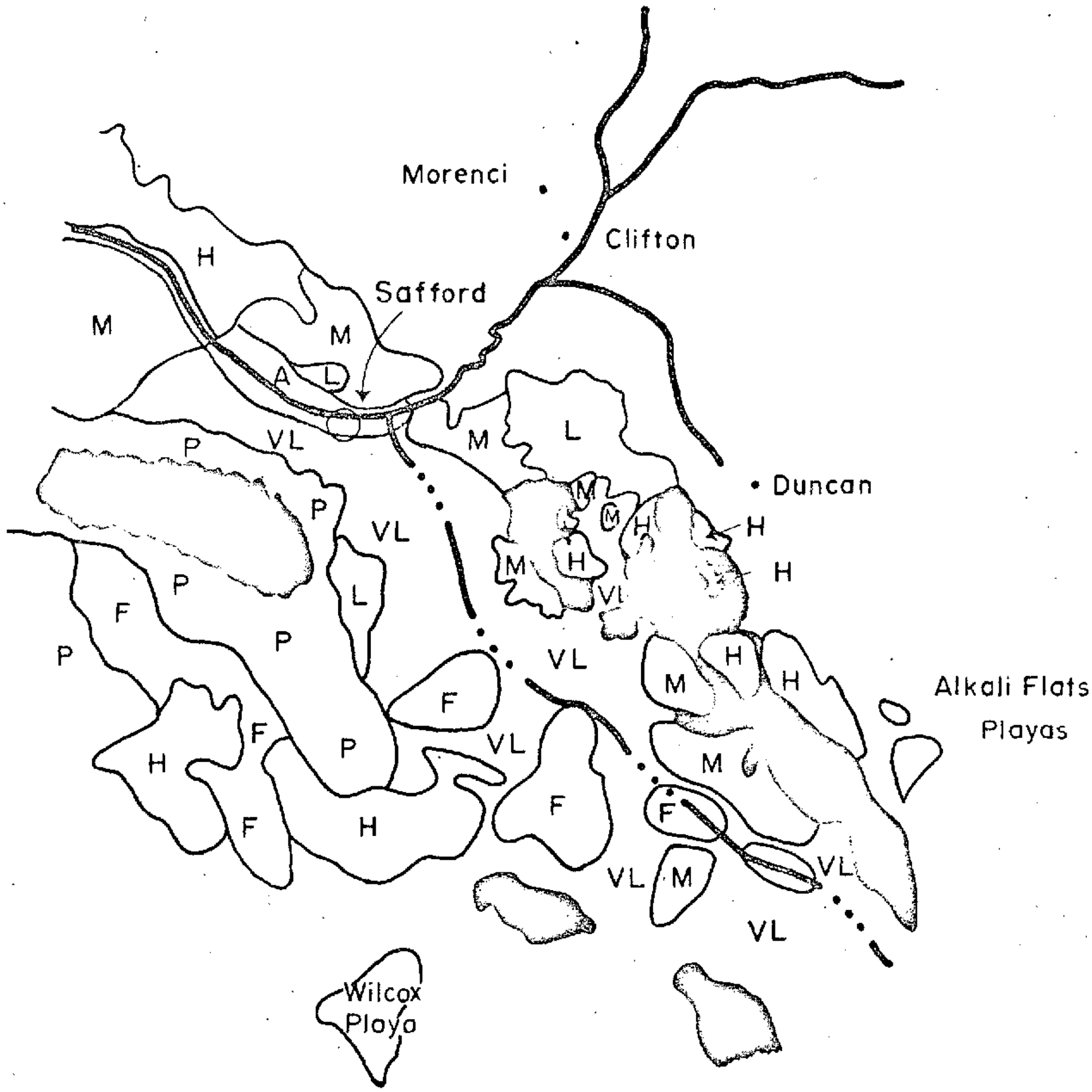
FIGURE 15. Ephemeral forage potential production map and areas producing wild flowers, taken from ERTS frames 1245-17222 and 17225, 25 Mar. 73.



LEGEND

H – High Potential
M – Moderate Potential
L – Low Potential
VL– Very Low Potential
A – Agricultural Land
P – Perennial Vegetation
F – Wild Flowers Area
Mountains

Although this analysis is very preliminary, it seems apparent that several significant characteristics of ephemeral vegetation distribution can be gleaned from satellite imagery taken during the spring growing season. It is significant to note that areas with a high potential for producing ephemeral forage conform to a geographic pattern somewhat similiar to that observed on the Phoenix-Tucson test site. High potential areas are found on upper bajada positions (Figure 16), deeper soils on desert mountains, and in small upper elevation valleys between mountain ridges; see Figure 17. This reflects the effect orographic lifting has on increasing precipitation.

Small areas of high ephemeral production potential can be identified and area boundaries accurately located. High potential areas appear very red on satellite imagery and this large contrast with surrounding blue or tan hues makes identification of boundaries very easy. Moderate potential areas showing a lighter red streaked with blue contrast less with their surroundings and boundary location is more difficult. Lower bajada sites and relatively flat lower elevation valley floors (Figure 18) have very low potential for producing ephemeral forage. This is especially true of the very saline soils, seen on Figure 14b as white or light gray streaked areas. Site aspect or the direction a slope faces does not appear to be a significant factor governing ephemeral production.

Large areas supporting dense stands of bladderpod appear on satellite image 1245-17225, Figure 14b, as yellow colored areas. Figure 19 shows how these sites appear on the ground. Bladderpod provides very little forage for livestock; therefore, areas producing dense stands would be classed in the very low forage potential category.

Theoretically, potential can be determined for natural resource uses other than livestock, especially if they are based upon the ability of a site to produce vegetation. The ability of a watershed to control water flow below damaging levels depends upon the ability of the soil to absorb water and grow an adequate cover of protective vegetation. Precipitation in the desert is not adequate to support dense stands of perennial herbaceous cover. However, a dense cover of ephemeral plants does provide protection to soil against water and wind erosion while they are growing and even some protection when they are dry as long as the plants remain in place as a soil covering. ERTS imagery can be used to locate sites where adequate ground cover can be predicted to occur, as well as those sites where ephemerals will be scarce.

It is well known that recreation is often oriented toward water. Where water is absent some other unique factor must serve as a stimulus to draw people. In the desert this stimulus can be topography, rock structures, or cacti and other flowering plants. Sites which have a high potential for producing ephemeral vegetation also produce the greatest quantity and variety

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FIGURE 16. Ground truth photo showing epehemeral vegetation growing on the upper bajada position. Photo taken 3-27-73 early in the ephemeral growing season.

(ODC-010052)

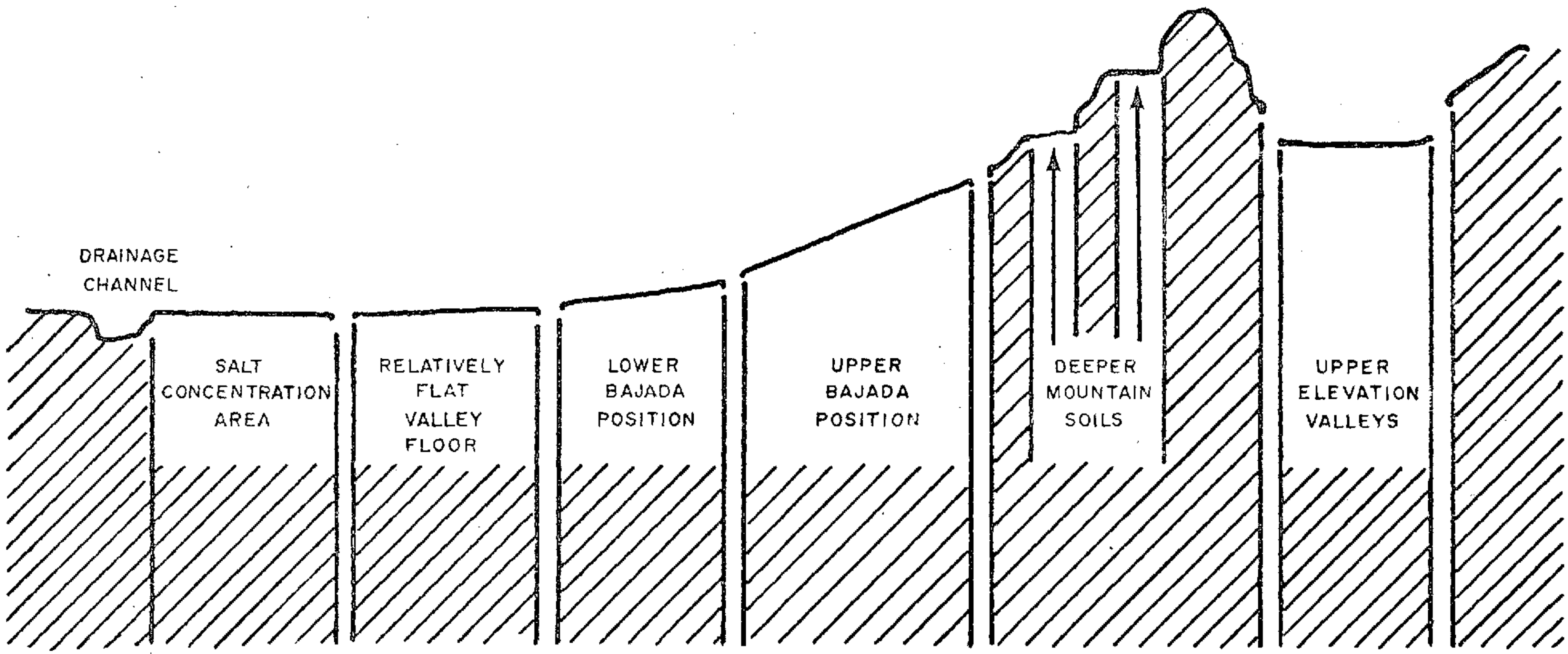

FIGURE 17. Cross-sectional view of topography as it affects ephemeral forage production.

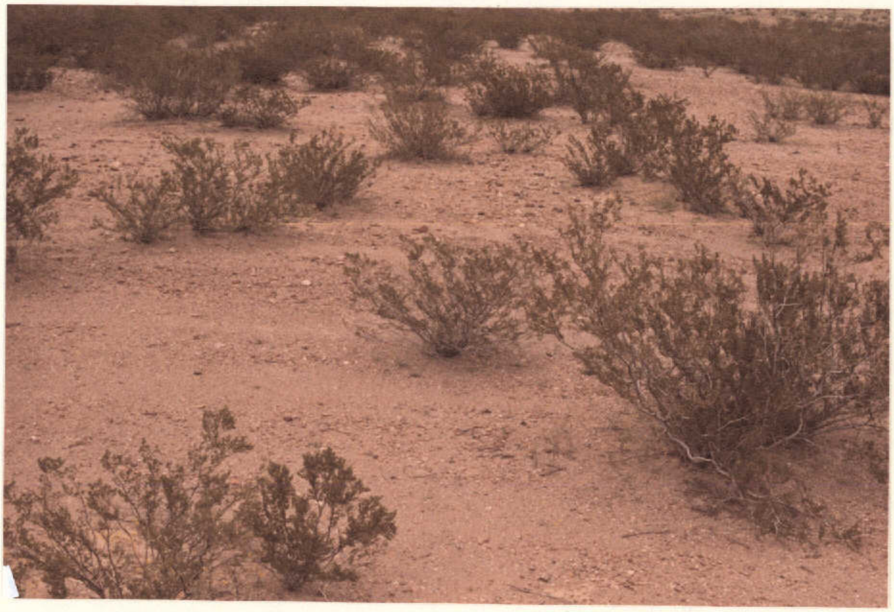

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FIGURE 18. A lower valley site with a very low potential for producing ephemeral forage.
(EDC-010053)

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FIGURE 19. A site producing a dense stand of Lesquerella gordoni -- bladderpod. Photo taken 3-27-73.
(EDC-010054)

of desert flowers, provide a pleasing aspect, and result in a somewhat moderated climate. Areas which produce dense stands of one plant species, such as the bladderpod stands shown in Figure 19 and designated as site F in Figure 15, are less desirable than sites producing a mixture of plants. A knowledge of the potential of sites to produce vegetation is very important to recreation planning.

B. California Site

1. Site Description

A study site was located in the arid desert 23 miles east of Indio, California, along Interstate 10. The site covers an area 20 miles by 14 miles including the valley on both sides of the freeway and the Orocopia Mountains to the south; see Figure 20. Annual precipitation is three inches; July temperatures average 77°F minimum to 115°F maximum and January temperatures average 38°F minimum to 70°F maximum. Elevations range from 1200 to 1600 feet on the valley floor up to 2000 to 3200 feet on the surrounding mountains. Native desert vegetation is very sparse, soils are light in color and contain varying amounts of sand.

2. Objectives

To determine if homogeneous tones-textures delineated on satellite imagery correspond to specific soil types, or do site factors such as aspect or basic geology have a greater influence on what can be seen on the imagery; also, determine how vegetation conforms to homogeneous areas identified on satellite imagery; and determine if there is a soil-plant relationship on broad areas covering several thousand acres.

3. Study Method

a. Analysis of Imagery

ERTS Frame 1070-17495, bands 5 and 6, 01 Oct. 72, were used in this study. Black and white paper prints at 1:1,000,000 scale, band 5, and 1:250,000 scale, band 6, were obtained from Goddard Space Flight Center. A close-up photo of the 1:250,000 image was also made of the immediate study areas at an approximate scale of 1:126,000; see Figure 21. All images were used in the analysis; however, the 1:126,000 image proved to be of greatest utility.

Images were analyzed visually by an interpreter. Boundaries were drawn around areas having a homogeneous gray tone and texture and recorded on overlay material. The polygons thus drawn were designated as sample areas and vegetation and soil measurements were made within each area.

FIGURE 20. Map showing the location of the ERTS test site in the California Desert, within the area covered by ERTS frame 1070-17495, 01 Oct 72.

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FIGURE 21. Photograph of a portion of ERTS image 1070-17495, band 6, 01 Oct 72. Approximate scale is 1:126,000; area covered is the Orocopia Mountains, 23 miles east of Indio, California.

b. Vegetation and Soil Measurements

Percent plant cover and species composition for all perennial plants were measured. Data was recorded by means of three 600 pace transects per sample area. A pace being each time the right foot touched the ground. A notch was placed in the sole of the right boot at the tip. The occurrence of live crown material for shrubs and trees and basal material for grasses was recorded by looking vertically at the notch. If live plant material was located in the line of sight to the notch, a hit was recorded; BLM (1972).

$$\frac{\text{No. of hits on live veg.}}{600} = \text{\% plant cover}$$

$$\frac{\text{No. of hits on X species}}{\text{No. of hits on live veg.}} = \text{\% composition of X}$$

Transects were placed end to end along a single line on all sample areas except the area encompassing the Orocopia Mountains. Because of rough topography, north and south facing slopes, and natural barriers, transects were separated. Soil data was collected from one soil pit in each sample area. Occurrence and depth of horizons, color of soil and soil texture were determined.

4. Results and Discussion

Eight distinct areas, each having a homogeneous gray tone and texture were delineated on satellite imagery. Figure 22 shows ERTS image 1070-17495, band 6, with those area boundaries superimposed over the image. Figures 23 through 30 show ground truth photographs of each sample area, illustrating vegetative community and soil surface characteristics of each. Under each photograph is a description of the soil and vegetative composition and percent ground cover.

Results of ground truth data collected within the areas outlined on satellite imagery show that differences seen on the imagery do reflect distinct soil characteristics. Therefore, soils can be mapped on a regional basis using satellite imagery to locate soil series boundaries. Perennial desert vegetation is so sparse in this region that it cannot be seen from space. Perennial plant cover averages from 2.7 to 7.1 percent of total ground area. However, vegetative communities on each of the sample areas was different and area boundaries can be used to help map vegetation on a regional basis.

The small size of this study made it impossible to test whether separate areas exhibiting the same tone and texture on satellite imagery also had similar soils. If such a direct correlation could be

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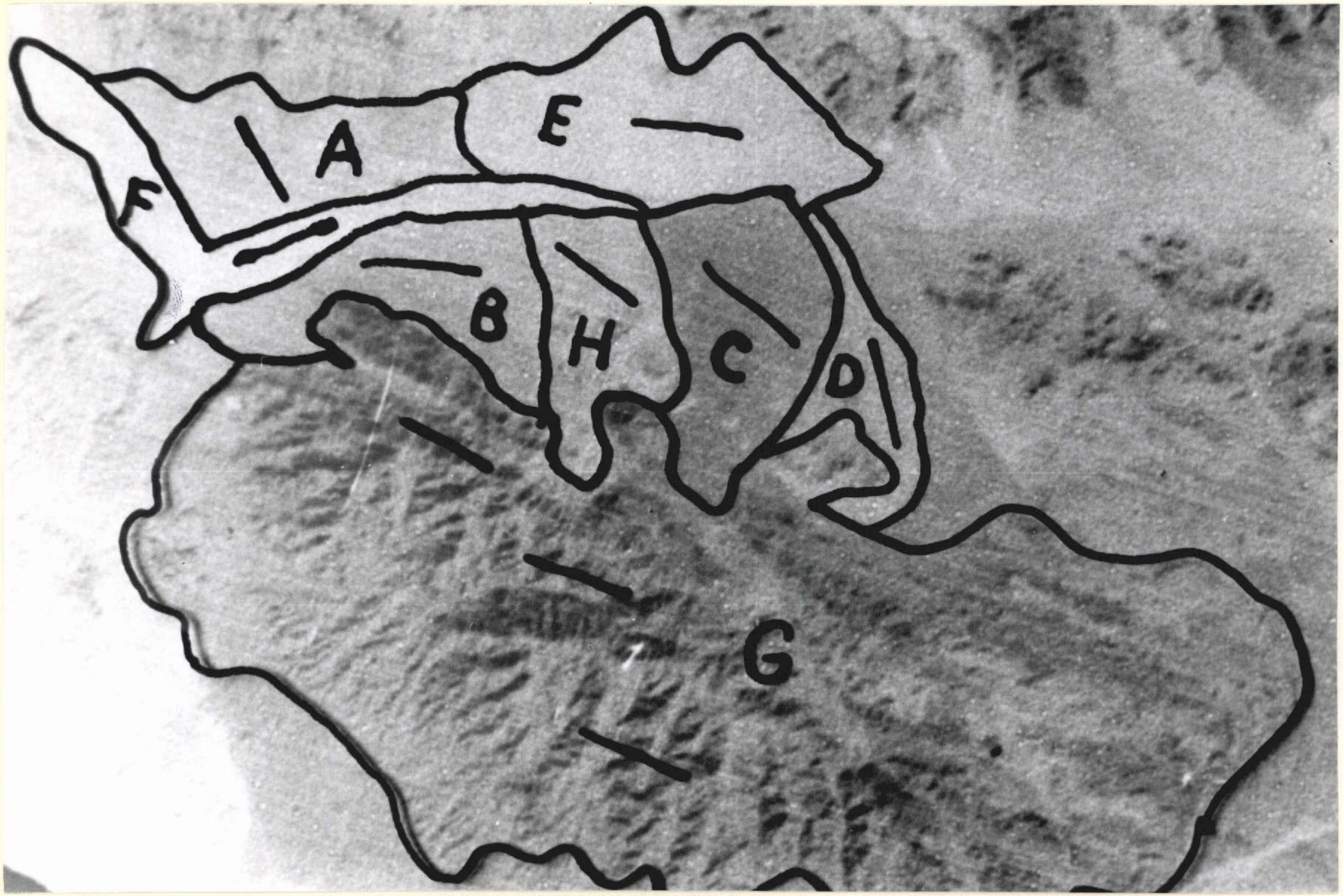

FIGURE 22. A portion of ERTS image 1070-17495, band 6, at a scale of 1:126,000, with boundaries drawn around areas having a homogeneous gray tone and texture.

FIGURE 23. Area A, Soil and Vegetation Ground Truth Data
(EDC-010055)

Soil Information: family: sandy-skeletal, mixed, hyperthermic
Series: Carrizo loam.

These soils have very pale brown to light brownish gray surface horizons with gravel and other coarse fragments exceeding 35 percent of volume between 10 and 40 inches.

Horizon Description

A_{11}	0-3"	gravelly loam, weak fine granular structure
A_{12}	3-7"	very gravelly loam, weak fine granular structure
C	7"+	very gravelly coarse sand, 60% coarse fragments

Vegetation Information: dalea - creosotebush - brittlebush type, 5.5% of ground surface covered by perennial plants.

Fouquieria splendens	ocotillo	4% of composition
Franseria dumosa	bursage	14% of composition
Larrea tridentata	creosotebush	26% of composition
Encelia farinosa	brittlebush	24% of composition
Dalea schottii	mesa dalea	12% of composition
Hymenoclea salsola	cheesebush	6% of composition
Hyptis emoryi	beesage	4% of composition
Assorted other shrubs		10% of composition
	TOTAL:	100%

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FIGURE 24. Area B, Soil and Vegetation Ground Truth Data

(EDC 010056)

Soil Information: Family: sandy, mixed, hyperthermic
Series: Carsitas sandy loam.

These soils have light brownish gray to light olive gray stratified upper horizons and light olive gray lower horizons. Averages sand to coarse sand at 10 - 40 inches depth.

Horizon Description

A_p	0-1"	silt loam, vesicular structure
A_1	1-5"	gravelly loam, massive structure, 20% coarse fragments
A_c	5-12"	sandy loam, massive structure, 50% coarse fragments
C	12"+	stratified sand, single grain

Vegetation Information: creosotebush - brittlebush - ocotillo type, 2.7% of ground surface covered by perennial plants.

Larrea tridentata	-	creosotebush	-	30% of composition
Encelia farinosa	-	brittlebush	-	47% of composition
Hyptis emoryi	-	beesage	-	4% of composition
Hymenoclea salsola	-	cheesebush	-	4% of composition
Dalea schottii	-	mesa dalea	-	8% of composition
Assorted other shrubs	-		-	7% of composition
		TOTAL:		100%

FIGURE 25. Area C, Soil and Vegetation Ground Truth Data
(EDC-010057)

Soil Information: Family: sandy-skeletal, mixed hyperthermic
Series: Tonopah loam.

These soils have pale brown to light gray brown surface horizons, coarse fragments exceed 35 percent at 10 - 40 inches, calcic horizon contains 15%+ calcium carbonate.

Horizon Description

A_p	0-1"	silt loam, vesicular layer, 10% coarse fragments
A_1	1-5"	gravelly weak fine structure, 40% coarse fragments
A_c	5-10"	gravelly loam, massive, 60% coarse fragments
C_{ca}	10-14"	loamy sand, weakly cemented
C	14"+	stratified very gravelly coarse sand

Vegetation Information: creosotebush - ocotillo type, 3.7% of ground surface covered by perennial plants.

Larrea tridentata	-	creosotebush	-	48% of composition
Franseria dumosa	-	bursage	-	20% of composition
Dalea schottii	-	mesa dalea	-	14% of composition
Krameria parvifolia	-	range ratany	-	4% of composition
Hymenoclea salsola	-	cheesebush	-	4% of composition
Hyptis emoryi	-	beesage	-	3% of composition
Opuntia ramosissima	-	pencil cholla	-	2% of composition
Encelia farinosa	-	brittlebush	-	1% of composition
Assorted other shrubs	-		-	4% of composition
		TOTAL:		100%

FIGURE 26. Area D, Soil and Vegetation Ground Truth Data
(EDC-610058)

Soil Information: Family: sandy-skeletal, mixed hyperthermic
Series: Carrizo loam

These soils have pale brown to brown surface horizons and gravel and other coarse fragments exceeding 35 percent of volume between 10 and 40 inches.

Horizon Description

A_1	0-4"	Coarse sandy loam, weak fine granular structure
A_C	4-10"	Gravelly loam, weak granular to weak fine sub-angular block structure
C_1	10-16"	Gravelly loam, weak granular structure
C_2	16"+	Stratified gravelly coarse sand with 60% coarse fragments

Vegetation Information: creosotebush-ocotillo-brittlebush type, 3.1% of ground surface covered by perennial plants.

Larrea tridentata	-	creosotebush	-	30% of composition
Encelia farinosa	-	brittlebush	-	14% of composition
Franseria dumosa	-	bursage	-	7% of composition
Dalea schottii	-	mesa dalea	-	18% of composition
Hymenoclea salsola	-	cheesebush	-	5% of composition
Lycium spp.	-	desert thorn	-	7% of composition
Assorted other shrubs	-		-	19% of composition
		TOTAL:		100%

FIGURE 27. Area E. Soil and Vegetation Ground Truth Data
(EDC-010059)

Soil Information: Family: sandy, mixed hyperthermic
Series: Carsitas coarse sand

These soils have light brownish gray to light olive gray stratified upper horizons and light olive gray lower horizons, sand to coarse sand at 10 - 40 inches.

Horizon Description

A_p	0-1"	silt loam
C	1-26"+	stratified coarse sand, single grain.

Vegetation Information: dalea-brittlebush-cholla type, 3.3% of ground surface covered by perennial plants.

Larrea tridentata	-	creosotebush	-	29%	of composition
Encelia farinosa	-	brittlebush	-	15%	of composition
Dalea schottii	-	mesa dalea	-	10%	of composition
Olneya tesota	-	ironwood	-	8%	of composition
Opuntia ramosissima	-	pencil cholla	-	14%	of composition
Franseria dumosa	-	bursage	-	10%	of composition
Assorted other shrubs	-		-	14%	of composition
		TOTAL:		100%	

FIGURE 28. Area F, Soil and Vegetation Ground Truth Data
(EDC-010060)

Soil Information: Miscellaneous Land type - Drainage wash

Area consists of unconsolidated alluvium, generally stratified and varying widely in texture, recently deposited by streams and subject to frequent changes. The deposits are too recent for soil profile development although the material may be mottled.

Vegetation Information: ironwood-paloverde-creosotebush type, 4.3% of ground surface covered by perennial plants.

Olneya tesota	-	ironwood	-	40% of composition
Cercidium microphyllum	-	paloverde	-	24% of composition
Hymenoclea salsola	-	cheesebush	-	12% of composition
Larrea tridentata	-	creosotebush	-	9% of composition
Encelia farinosa	-	brittlebush	-	5% of composition
Assorted other shrubs	-		-	10% of composition
		TOTAL:		100%

FIGURE 29. Area G, Soil and Vegetation Ground Truth Data

(EDC-010069)

Soil Information: Miscellaneous Land type - Rock Outcrop

This area contains more than 90 percent rock outcrops and is steep to very steep. This area is made up of Oligocene non-marine sedimentary and pre-cretaceous metasedimentary rocks.

Vegetation Information: bursage-creosotebush type, 7.1% of ground surface covered by perennial plants.

Franseria dumosa	-	bursage	-	44% of composition
Larrea tridentata	-	creosotebush	-	26% of composition
Lycium spp.	-	desert thorn	-	5% of composition
Encelia farinosa	-	brittlebush	-	12% of composition
Ephedra nevadensis	-	mormon tea	-	3% of composition
Viguiera deltoidea	-	desert-sunflower	-	4% of composition
Krameria parvifolia	-	range ratany	-	2% of composition
Hofmeisteria pluriseta	-	arrow-leaf	-	2% of composition
Sphaeralcea rosacea	-	globe mallow	-	2% of composition
		TOTAL:		100%

FIGURE 30. Area H, Soil and Vegetation Ground Truth Data
(EDC - 010062)

Soil Information: Family: sandy-skeletal, mixed hyperthermic
Series: Carrizo loam

These soils have very pale brown to light brownish gray surface horizons and gravel and other coarse fragments exceeding 35 percent of the volume between 10 and 40 inches.

Horizon Description

A_1	0-3"	sandy loam, weak fine granular structure, slightly hard, few clay films
A_c	3-12"	gravelly loam, weak fine granular structure, many clay films
C	12"+	stratified gravelly coarse sand with 80% coarse fragments

Vegetation Information: creosotebush-brittlebush-ocotillo type, 3.0% of ground surface covered by perennial shrubs.

Larrea tridentata	-	creosotebush	-	36% of composition
Franseria dumosa	-	bursage	-	15% of composition
Encelia farinosa	-	brittlebush	-	7% of composition
Dalea schottii	-	mesa dalea	-	9% of composition
Hymenoclea salsola	-	cheesebush	-	6% of composition
Hyptis emoryi	-	beesage	-	2% of composition
Lycium spp.	-	desert-thorn	-	7% of composition
Cercidium microphyllum	-	paloverde	-	6% of composition
Fouquieria splendens	-	ocotillo	-	4% of composition
Assorted other shrubs	-		-	8% of composition
		TOTAL:		100%

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found to exist, a tremendous saving of manpower would result. The technique outlined by this study would represent a very significant decrease in time previously required to map soils and vegetation. A two man team can map soils and vegetation on 100 square miles in four to five days.

Detailed soil and vegetation mapping is a fairly simple straight forward process. Pretyping can be done on aerial photographs of 1:20,000 scale, for example. Soil and vegetation type boundaries are then checked on the ground and detailed information gathered for each type. With many hundreds of photographs of scale 1:20,000 required to cover large areas, regional mapping has had to depend upon visual estimates of people traversing the landscape. Satellite imagery has created a new tool which allows the observer to look at large areas at one time.

During the course of the study, observers found that small details, seen while traversing a sample area, are obscured on small scale satellite imagery. This is an advantage when mapping on a regional basis. Many changes in soil surface characteristics and plant groupings over small areas make it difficult for observers to map on a regional basis entirely from observations made on the ground. Ground truth data has shown that small differences in vegetation found throughout a given sample area were not as significant as those differences existing between sample areas.

C. Oregon Site

1. Site Description

The study area is located in the southeastern corner of Oregon (Figure 31) in a rolling plains country bisected by small drainage patterns which drain north into the Owyhee River. The region is dotted with large playas (dry lakes), lave flows, revegetation projects (man-made grass seedings) and wildfire areas. Elevation ranges from 4500 feet in the north and west to over 6000 feet in the south and east. Precipitation averages 8-10 inches annually, coming mostly in winter and spring. Vegetation is predominantly sagebursh and native perennial bunch grasses.

2. Objectives

Utilize satellite imagery to:

a. Locate, identify and plot boundaries of natural and cultural (man-made) features.

b. Plot boundaries of broad soil types and classes of vegetation.

c. Monitor effects of grazing management systems.

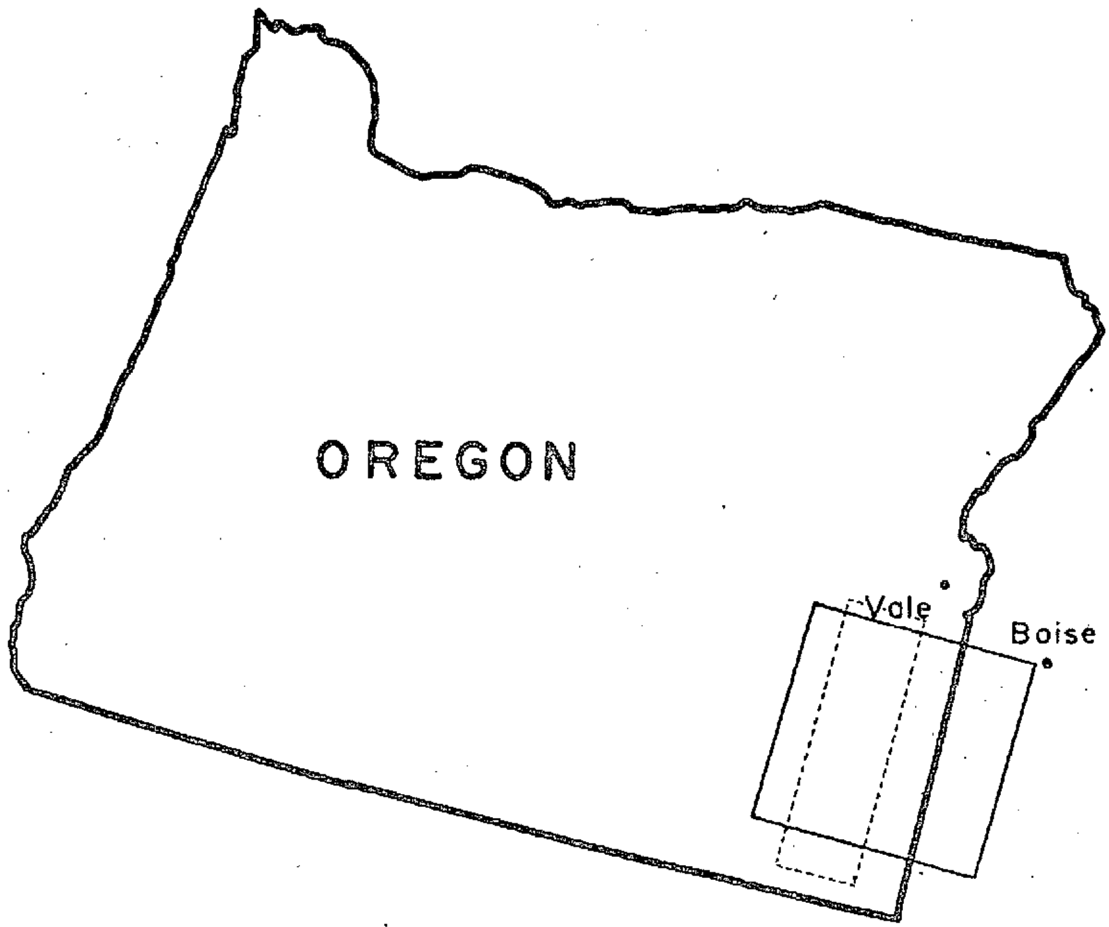

FIGURE 31. Map showing the location of the ERTS test site in Oregon (dashed line) and the area covered by imagery received (solid line).

3. Study Method

a. Climate

A weather station was located in the southeast corner of the test site. Satellite rain gauges were located throughout the study area. The following weather data was collected:

(i) Precipitation
(ii) Temperature
(iii) Wind movement

b. Vegetation Measurements

The following vegetation measurements were made in each pasture on both native and seeded ranges:

(i) Percent ground cover of perennial plants
(ii) Percent species composition of perennial plants
(iii) Pounds of forage production -- perennial and annual forage plants
(iv) Stage of plant growth

Items iii and iv were measured at four dates, coinciding with overpass of the satellite -- May 8, May 26, June 13 and July 1.

The extent of grazing on each pasture was recorded in the form of dates each pasture was grazed and the number of animal unit months (AUM) of grazing. One cow grazing for one month equals one AUM.

c. Analysis of Imagery

Imagery used in the analysis was in the form of color composites produced by the Goddard Space Flight Center, Sioux Falls Data Center, and by the Principal Investigator using the triple-exposure camera technique; see Section II. Contact prints at 1:1,000,000 scale were used as well as blow ups of a specific area at 1:350,000 scale.

Analysis of imagery was done visually by an interpreter. No special equipment was used. Cloud cover on all imagery received during the spring growing season made analysis of vegetation very difficult.

4. Results and Discussion

Very little usable imagery was received during the study period. All imagery received during the spring growing season was heavily cloud covered over the test area. Imagery used in this study is as follows:

E-1019-18041*	11 Aug. 72
E-1253-18052	02 Apr. 73
E-1289-18051	08 May 73

Figure 32 illustrates a washed out color composite satellite image caused by the high (large) sun angle during summer. This frame also indicates why high flight imagery from Flight No. 72-128, taken July 28, 1972, was not very useful. By this date, the growing season had ended, plants were dormant and reflected very little energy in the near infrared region.

Figure 33 illustrates color composite satellite imagery received during the spring growing season for the Oregon test site and the analysis problems created by clouds. Unfortunately, an even greater problem exists. Detailed ground truth data was collected only on the portion of the test site near the Nevada border as shown in Figure 31. This area was selected for detailed analysis because two large areas, one grazed according to a grazing management system and one grazed season long existed adjacent to one another. Because of these two problems, only tentative results can be reported at this time.

Temperatures during the first half of the growing season (April and May) were fairly cool resulting in below normal plant growth. By May 8, when satellite Frame 1289-18051 was taken, plants had been growing slowly for only two to three weeks. Precipitation was about average for April and May, but plants were not able to fully utilize this moisture because of low temperatures. By June and July when temperatures were adequate for growth, soil moisture was low and precipitation for those months below normal.

Precipitation for the Study Area

Month	Inches of PPT
April	1.00
May	1.10
June	0.60
July	0.35

An enlargement of the 08 May 73 satellite imagery, at an approximate scale of 1:350,000, for the area closest to the test site, was analyzed; Figure 34. Analysis indicates that boundaries of revegetation projects can be mapped and development of vegetation monitored.

*NOTE: Frames purchased from the Sioux Falls Data Center in form of 9x9 inch positive transparencies in MSS bands 4, 5, & 6.

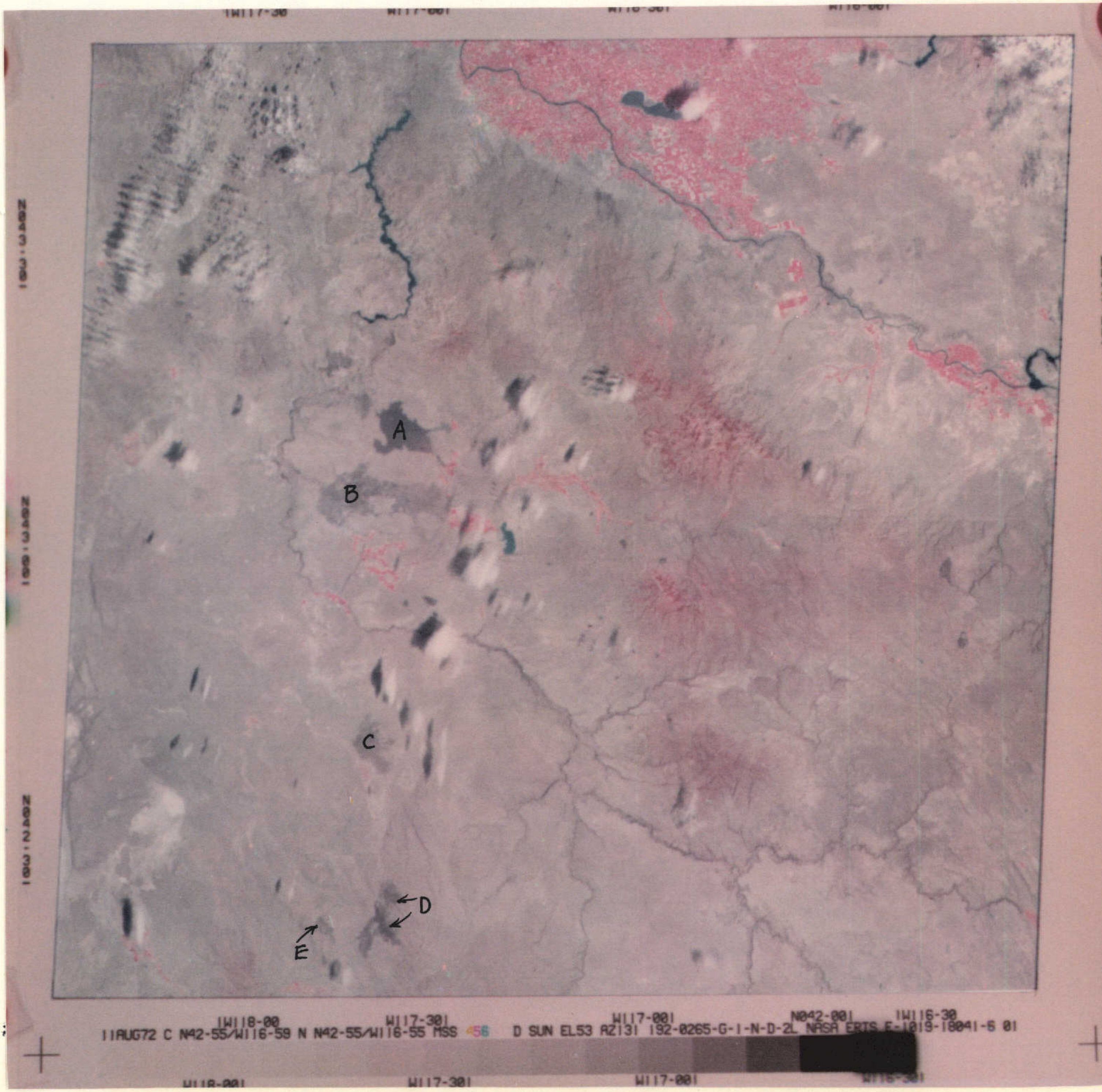

FIGURE 32. Color composite image of ERTS frame 1019-18041, 11 Aug. 72, showing washed out image and lack of detail. (EDC-010063)

A - New lava flow

B - Old lava flow

C - Winter Range fire, 6-23-72, 14,080 acres

D - Battle Creek fire, 8-9-72, 13,120 acres

E - Blue Mountain fire, 6-30-72, 1,920 acres

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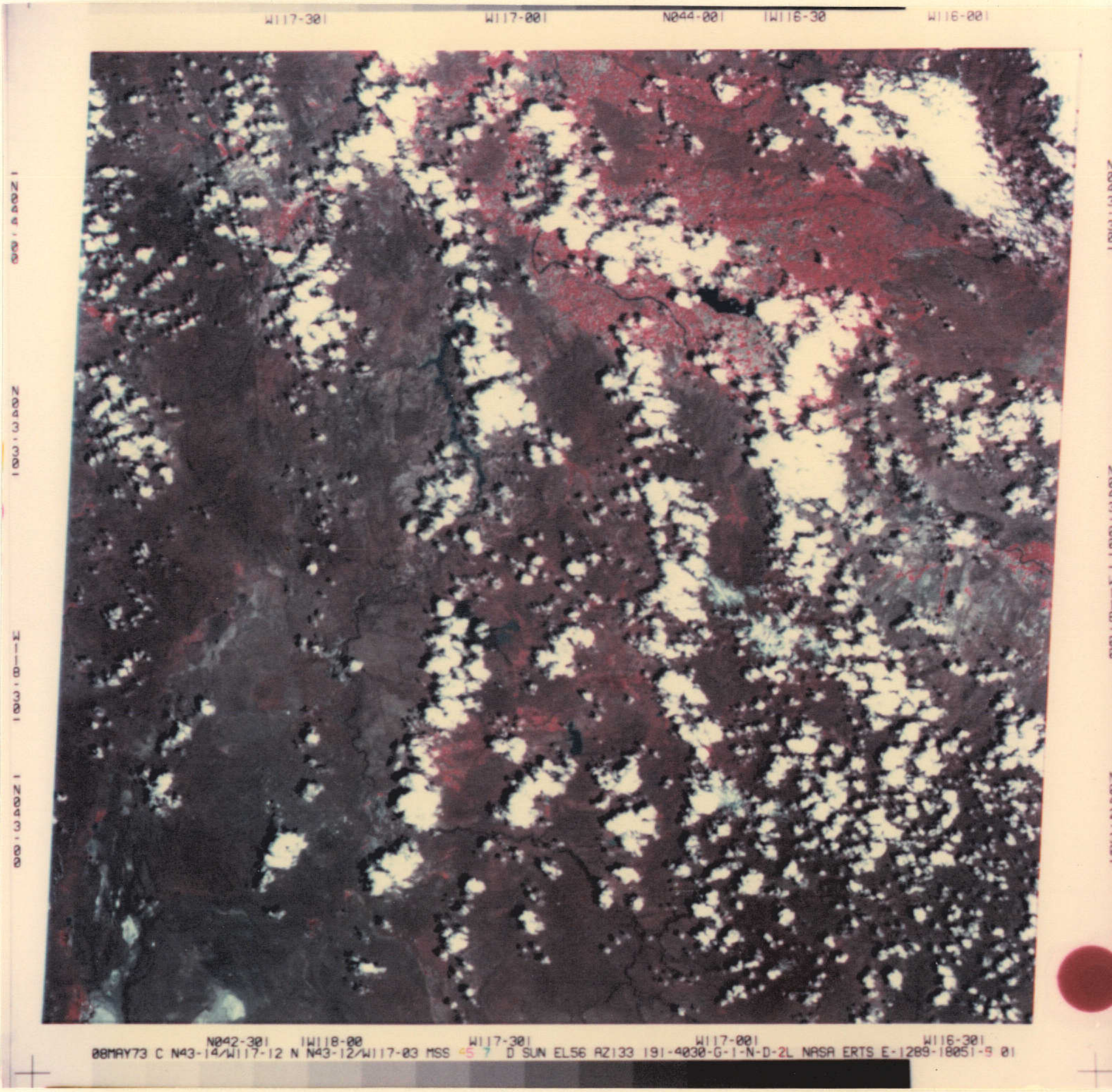

FIGURE 33. Color composite image of ERTS frame 1289-18051, 08 May 73, scale 1:1,000,000. Note the effect cloud cover has on the ability to discern detail.

(EDC-010064)

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FIGURE 34. Enlargement of the southwest corner of ERTS frame 1289-18051, 08 May 73. Approximate scale 1:350,000.(EDC·0100065)

A - Areas where Artemisia tridentata -- big sagebrush -- was plowed and area seeded to Agropyron cristatum -- crested wheatgrass

B - Areas where sagebrush was killed by aerial application of chemical and native grass has filled in

C - Wildfire areas

D - Hay meadows

E - Area producing big sagebrush on a basalt soil

F - Area producing a good mixture of big sagebrush and native grasses

G - Hill country producing a good mixture of big sagebrush and native grasses (Sheepshead Mtns.)

H - Saline area producing Atriplex confertifolia -- shadscale

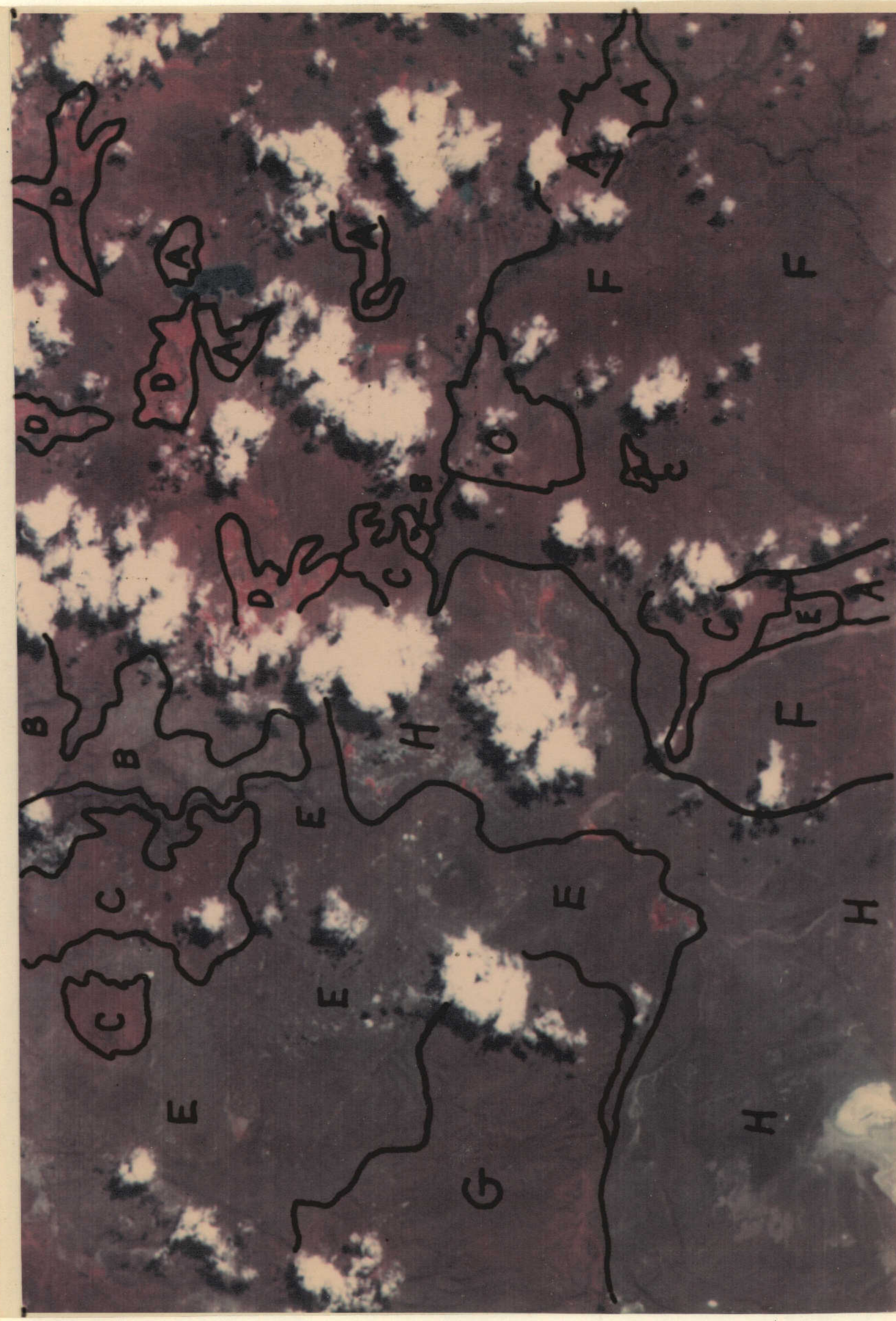

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FIGURE 34

Progress of plant growth during the growing season would be important input into decisions to move livestock according to a grazing management schedule. Areas designated as A in Figure 34 have had Artemisia tridentata -- big sagebrush -- removed by plowing and have been seeded to Agropyron cristatum -- crested wheatgrass; also, see Figure 35. Areas designated as B in Figure 34 were sprayed with a chemical to kill sagebrush and the areas now support a good mixture of native grasses and forbs; also see Figure 36.

Native plant communities can be separated and mapped on ERTS color composite imagery if sufficient differences exist between growth form of plants and amount of infrared reflectance. Driscoll and Francis (1972) also found that "native plant communities of habitat types" could be mapped where "image boundary characteristics (were) markedly different from adjacent units." Grasses reflect more infrared energy than does sagebrush. Grass areas appear pink to red and sagebrush areas appear bluish-purple with red intermixed. The density of sagebrush depends upon which color, red or blue, dominates the scene.

The following vegetative communities can be distinguished on the enlargement of the 08 May 73 ERTS frame in Figure 34.

Area H covers sites with saline soils producing predominately Atriplex confertifolia -- shadscale -- with a small amount of grass understory. Area E is a basalt region producing heavy stands of big sagebrush with a fair understory of grass. Area F is a more productive site producing a good mixture of big sagebrush and native bunch grasses such as Agropyron spicatum -- bluebunch wheatgrass, Poa secunda -- sandberg's bluegrass, Sitanion hystrix -- squirreltail and Festuca idahoensis -- Idaho fescue. Where contrast between sites is not so great, such as big sagebrush-grass versus Artemisia arbuscula -- low sagebrush-grass, site boundaries may not be distinguishable; see Figure 37.

Areas burned by wildfire during the current growing season show up black on ERTS imagery, as do lava flows; see Figure 32. Only ground truth can determine the differences.

Satellite imagery can also be used to monitor burned areas through subsequent growing seasons. Old burned areas are designated as C in Figure 34 and show up as pink or red, indicating a covering of grass now inhabits the sites. In the late summer and fall these areas will show as a light straw color when grasses go dormant; see Figure 38.

Potential of an area to produce livestock forage is indicated by a dark red color on satellite imagery. For example, area F in Figure 34 is more productive than either area E or area H. Area G also produces more forage, but it may be less useful because of topography of the hills. Areas C (burns) and A (seedings) produce large amounts of forage because of

FIGURE 35. Top photo shows an area seeded to <u>Agropyron cristatum</u> -- crested wheatgrass; May 8. Bottom photo shows a similar area as seen from the air; note distinct boundaries.

Top (EDC-010066) Bottom (EDC-010067)

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FIGURE 36. Top photo shows an area where Artemisia tridentata -- big sagebrush -- has been killed by aerial application of chemicals. Note dead brush and thick stand of healthy grasses. Bottom photo shows a similar area in foreground as viewed from the air. Note fenceline contrast. Top (EDC-010068) Bottom (EDC-010069)

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FIGURE 37. Top photo shows a mixed stand of big sagebrush and grass. Bottom photo shows a mixed stand of low sagebrush and grass. Such sites may be difficult to separate on satellite imagery.
Top (EDC-010070) Bottom (EDC-010071)

FIGURE 38. Area burned by wildfire shows straw color (dry grass) as opposed to the darker native sagebrush range in foreground. (EDC-610072)

a lack of competition with sagebrush. However, it is interesting to note that area F shows a deeper red, indicating more herbaceous vegetation than do areas A and B. This may be an indication that plant density on treated area A has not yet reached that found on area F after being disturbed by plowing. Density on the seedings averages one crested wheatgrass plant per square foot. Density is greater on the native range in area F but plants are shorter. On May 8 all grasses were less than 6 inches tall on all areas. The lighter color on areas A may also indicate that area F is naturally a more productive site.

No information is available which would explain why areas B appear so light. However, ground control examinations did show that plants on some sites were much slower to begin growth and this was a very cool spring. Grass plants growing in the protection of larger shrubs (area F) may enjoy a temperature advantage over those growing in the open and exposed to free air movement (areas B); see Figure 36, top photo.

No opportunity existed to determine whether site differences due to grazing could be seen on satellite imagery.

Images at an approximate scale of 1:1,000,000 (full frame) and enlargements of a portion of a scene were both produced in the same manner using 9x9 inch positive transparencies and the triple-exposure camera technique. It is interesting to note, however, that enlargements yielded the greatest amount of information. Colors were more true on the enlargements, and much greater detail could be seen. An area which appeared homogeneous in tone on the 1:1,000,000 scale image often times could be separated into several distinct areas on a three time enlargement. Natural features and vegetative boundaries were more sharp on enlargements.

D. Alaska Site

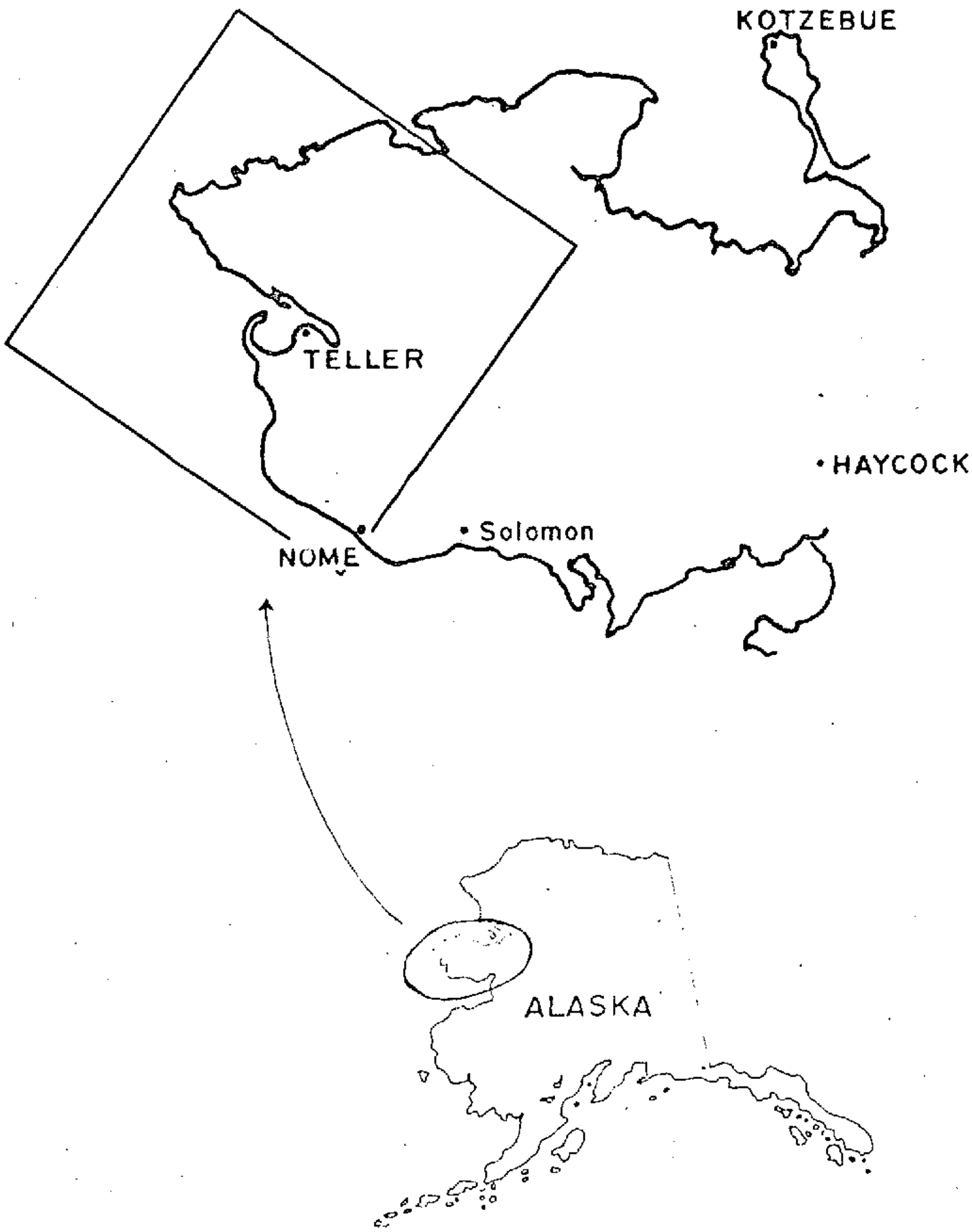
1. Site Description

The study site was located on the Seward Peninsula in the Nome area; see Figure 39. Later, a request was made to NASA to expand the site over more of the Peninsula.

2. Objectives

The objective of this study was to determine if satellite imagery could be used to map broad categories of vegetation in Alaska. Because of the tremendous size of Alaska and difficulty of travel, very little ground truty data exists to back up vegetative type mapping done in the past. Satellite imagery could provide a useful tool for mapping vegetation.

FIGURE 39. Map showing the Alaska test site on the Seward Peninsula.



3. Study Method

Vegetation ground truth data was gathered by driving the three main roads leading out of Nome. Vegetation communities were mapped on the Nome 1:250,000 U.S.G.S. quadrangle map from ground truth data, 1:20,000 scale aerial photographs and knowledge of BLM resource people living in the area; see Figure 40. Vegetation boundaries were checked during reconnaissance flights in light aircraft. General view oblique photographs using color and color infrared film were also taken of the different vegetative communities during the flights. Color infrared photos were used to give some idea of the different color tones resulting from various species of plants. These tones were then compared with tones seen on the satellite imagery.

4. Results and Discussion

Ground truth data as shown in Figure 40 was collected during August 1972, before BLM interpreters had a chance to view satellite imagery. No usable satellite imagery was received from NASA, partly because of cloud cover. A color composite of ERTS Image 1009-22095, 01 Aug. 72, was received from Doctor Albert Belon, Geophysical Institute at the University of Alaska; see Figure 41. An attempt was made during July 1973 to compare homogeneous hues, tones and textures located on the imagery with vegetative communities in remote areas. Bad weather made aerial reconnaissance impossible. A 1:250,000 enlargement of ERTS Image 1009-22095 was obtained from the University of Alaska and another attempt was made in August and September to compare this imagery with ground data. Bad weather again made this impossible.

As it was impossible to extend the boundaries of ground truth data beyond that collected in 1972 (Figure 40), accurate results can only be reported for that area. Interpretations from imagery at a scale of 1:1,000,000 (Figure 42) compare favorable with the ground truth data and also with work done by Anderson and Belon (1973) on the same ERTS frame. The main difference between plant community boundaries drawn from ERTS imagery and those drawn from ground truth is the level of detail. Subtile changes in boundaries cannot be detected on imagery with a 200-300 foot resolution capability.

Detailed analysis was not attempted on portions of imagery covering areas where ground truth data was lacking. However, a cursory examination by BLM people familiar with the area showed that work done by Anderson and Belon analyzing imagery without benefit of ground truth data was fairly accurate. Boundaries drawn around distinct plant communities were very accurate, considering mapping was done on a regional scale. Kinds of vegetation indicated by Anderson and Belon were fairly accurate with some exceptions.

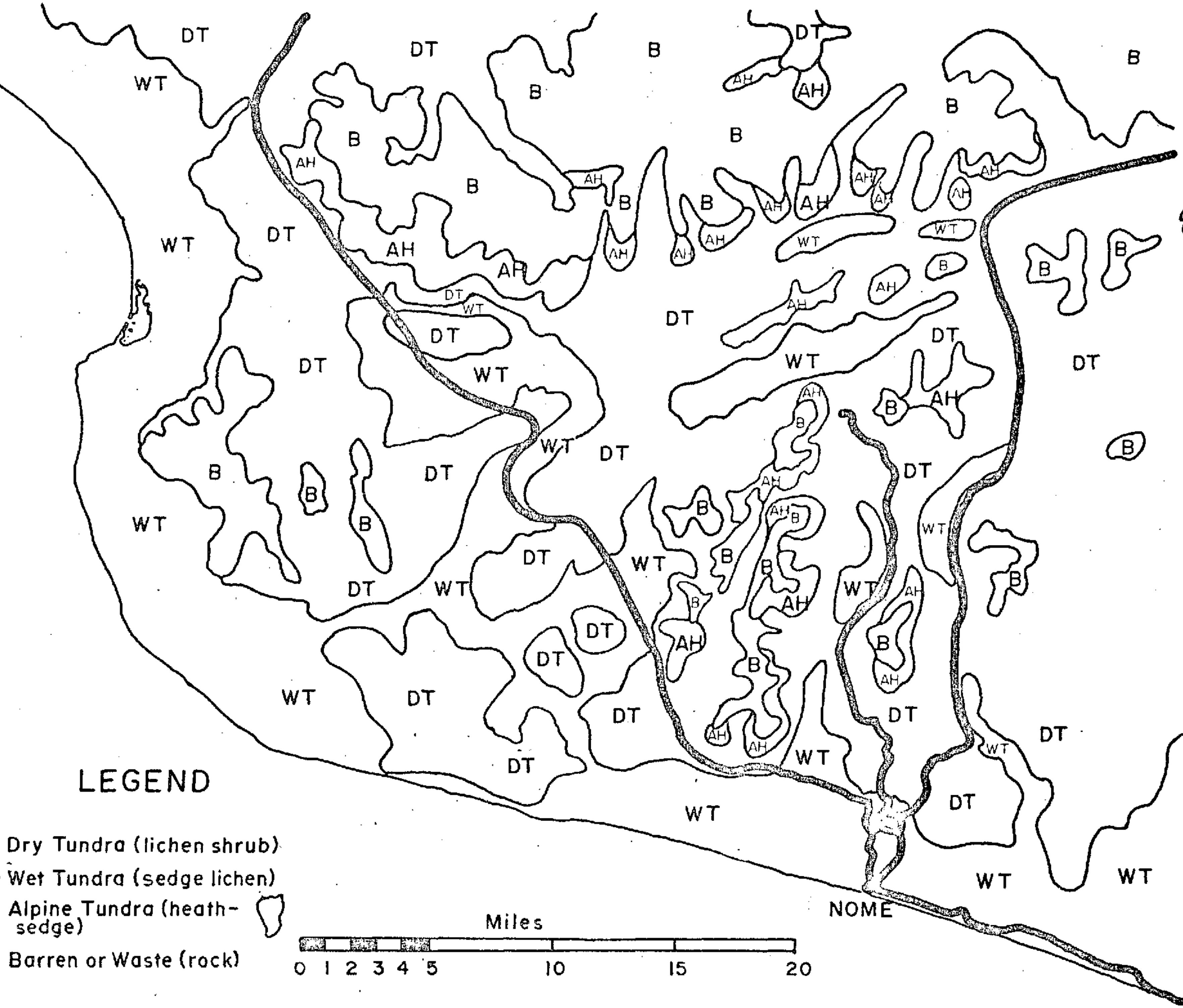


FIGURE 40. Ground truth data for the Nome-Teller area collected during August 1972.

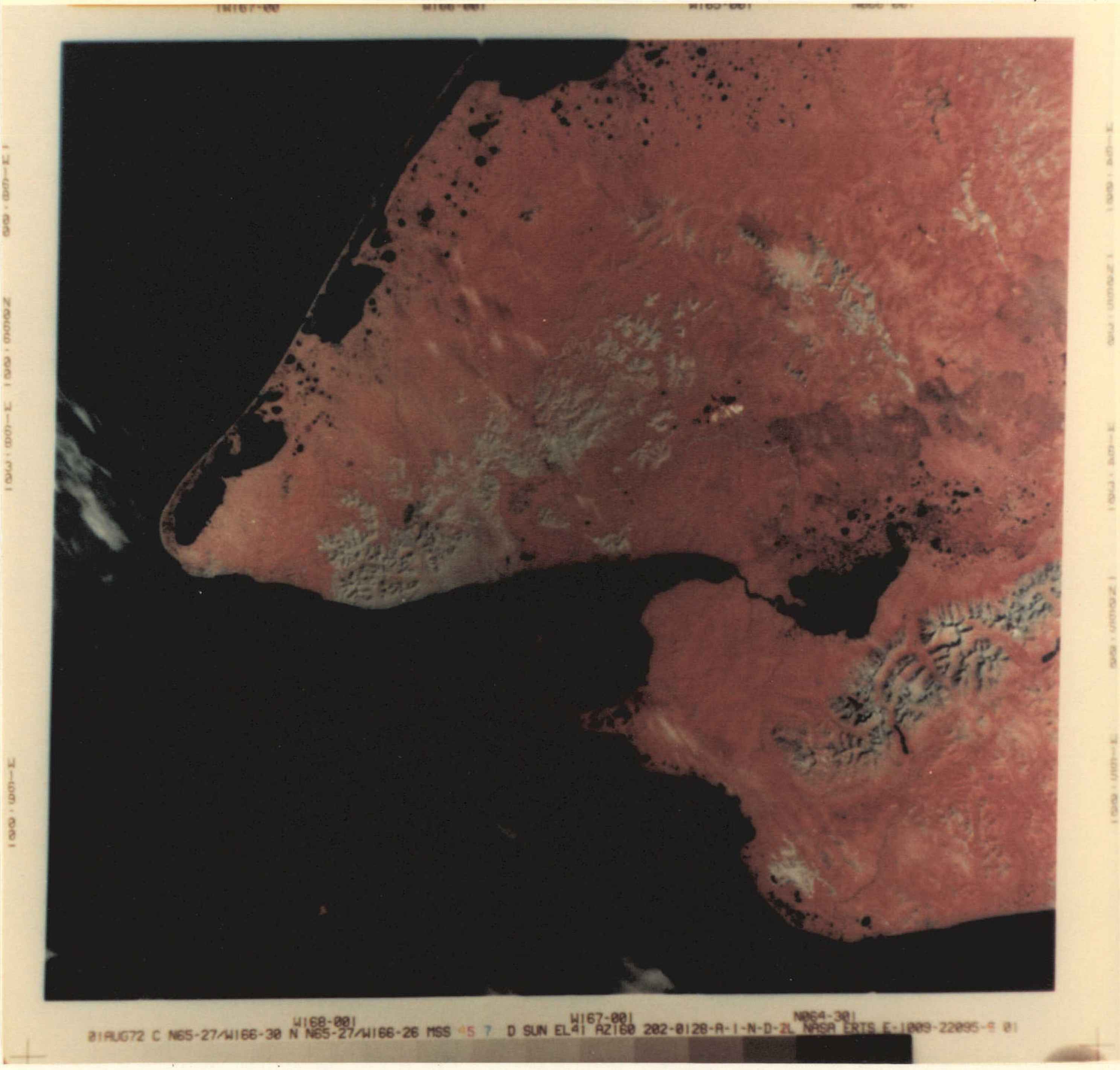


FIGURE 41. Color composite image of ERTS frame 1009-22095, 01 Aug. 72, of the Seward Peninsula, Nome-Teller area. (EDC · 010073)

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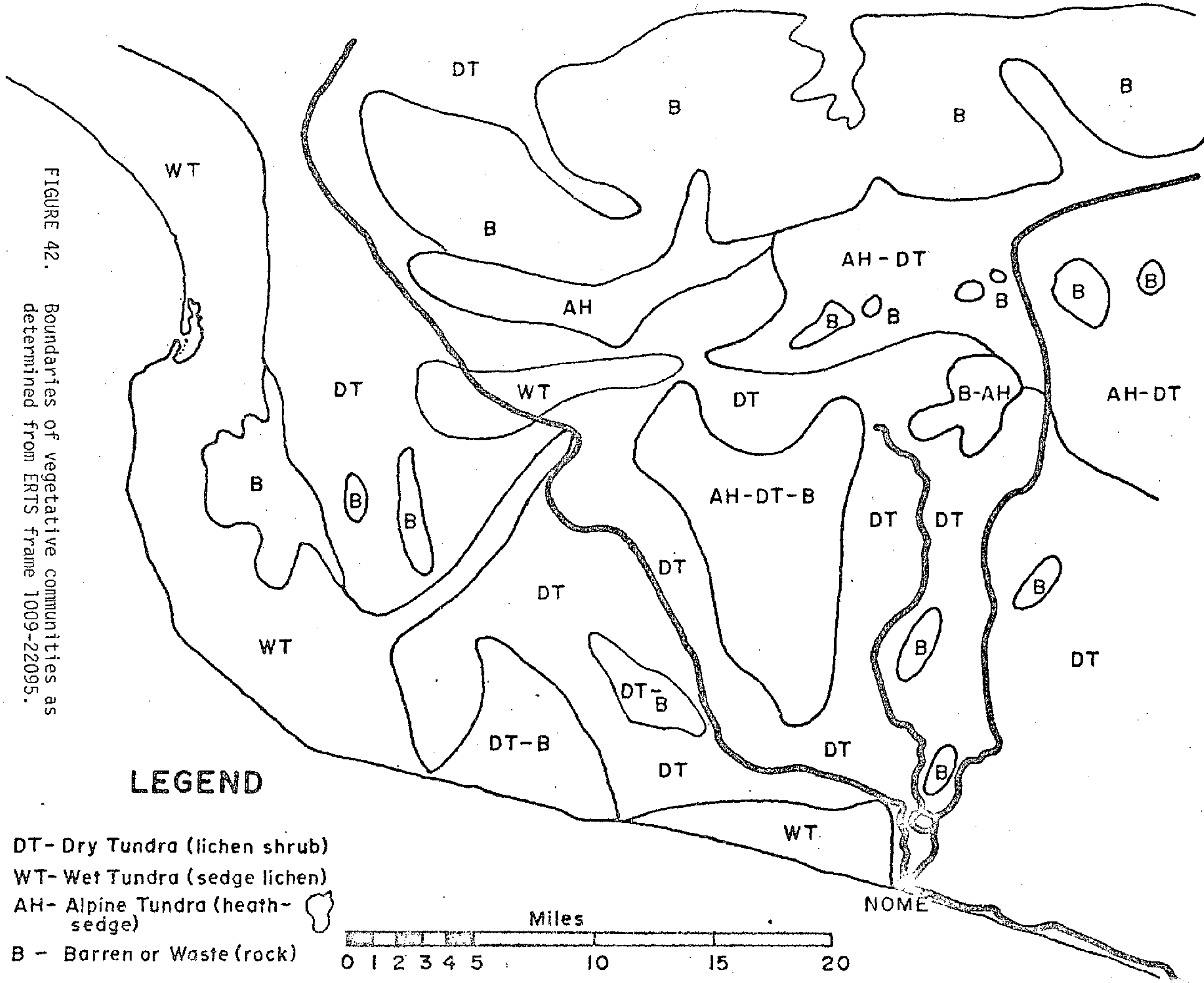

FIGURE 42. Boundaries of vegetative communities as determined from ERTS frame 1009-22095.

For example, areas designated as senescent vegetation (5)* are probably upland tundra (2). They appear light in color because of the white inflorescences of Eriophorum angustifolium -- cotton grass. Vegetation mosaic, shrub thicket/alpine barrens (10), should also include the upland tundra type. Upland tundra is designated as dry tundra in Figure 40. Burned areas are covered with a shrub thicket/upland tundra mosaic (8) vegetation with a high percentage of cotton grass. Since being burned, the areas have a general aspect of cotton grass although small shrubs and sedges are still a part of the community. Some shrub thicket/upland tundra mosaic areas also support a fairly high percentage of arctic grasses.

Areas designated as grassland tundra (7) are a sedge-grass type with a high percentage of both kinds of vegetation. Generally the aspect appears to be a grassland except in August when cotton grass is in bloom. The small area (11), designated by Anderson and Belon as shrub thicket/upland tundra/alpine barrens mosaic, located east of a barren area (6) near the coastline north of Sledge Island, is actually an upland tundra site (dry tundra) with two barren outcrops in the center.

ERTS frame 1312-21533, 31 May 73, was analyzed. The image was covered with a thin layer of clouds and some snow and was not very usable. However, two large burned over areas could be seen. An enlargement at a scale of 1:247,000 was made. The boundary of burned area was very clear and could easily be charted to determine acreage burned. In addition, unburned islands were clearly visible. Several areas darker than the surrounding burned area indicate some kind of site difference, variation in burning intensity, or differential effect of the fire. No ground truth is available. The important thing is the level of detail that can be seen on satellite imagery, especially when enlarged. Detail is improved greatly through enlargement rather than degraded. When accompanied by ground truth data, satellite imagery can be a very effective tool.

These results, while tentative, indicate that satellite imagery can be a very useful tool for mapping vegetation in Alaska on a regional basis. However, ground truth data is a necessary part of the system. This reporter has also viewed enlargements of ERTS color composites at 1:250,000 scale, produced by the University of Alaska. Based on the excellent quality of the imagery and preliminary work being carried on by James H. Anderson, I believe that imagery of this scale and quality would be sufficient to allow BLM resource managers to do fairly detailed mapping in Alaska. Both regional and detailed vegetation analyses can provide useful information in guiding those who must make management decisions regarding the use of resources in the Arctic and sub-arctic.

NOTE: Numbers in parentheses are taken from Anderson and Belon and refer to the kinds of vegetation listed on their map on page 7.

IV. SUMMARY AND POTENTIAL APPLICATION OF RESULTS

Satellite imagery can be a useful data gathering tool for Bureau of Land Management resource managers. This statement is based on results obtained in studies conducted by BLM in a variety of geographic locations and under varied conditions. Results can be summarized by study area.

A. Arizona Study Sites

Broad categories of vegetation in south central and southeast Arizona can be separated on ERTS color composite satellite imagery. Areas which support very little perennial vegetation, a very thin stand of creosotebush, and a majority of ephemeral plants in season can be separated from areas which support a dense cover of mixed perennial trees and shrubs and an understory of ephemerals in season. Several broad categories of ephemeral forage production in each vegetative category can also be mapped on satellite imagery; see Figure 7.

Based on the results of one growing season, there is strong indication that areas can be segregated according to their potential to produce ephemeral forage. Figure 13 outlines a tentative potential production map for the Phoenix-Tucson test site, and Figure 15 shows a similar map for the Safford area, southeastern Arizona. Based on preliminary data on which could be seen slight changes in growth of ephemeral plants early in the season and ephemeral plants drying out at maturity at the end of the growing season, it would seem feasible that growth of plants during the entire growing season could also be monitored. Figure 14b also shows that in some cases a phenologic stage such as flowering can be seen when plants are dense enough for flower color to show up on the imagery.

Recreation is another use of the land which BLM must consider. It is a use which can be made concurrent with livestock grazing, if grazing is properly controlled. Winter in Arizona is usually characterized by mild temperatures. Visitors come from colder climates to see the unique topography and vegetation of the desert. Desert flowers are a well known tourist attraction. Winter ephemerals are primarily forbs (herbaceous flowering plants) which offer a variety of kinds and colors of flowers; see Table I. Results of this study show that the greatest variety of flowers in the low desert of central Arizona are found in the Perennial - Ephemeral sites (tree-shrub) in the heavy ephemeral production class. While the Ephemeral sites (creosotebush) produce more pounds of ephemeral livestock forage, the variety or number of species of ephemeral plants is much lower; see Table I. Often only one or two species are found on any one given site. In the high desert of southeastern Arizona, the greatest variety of flowering plants are found on those areas where production of ephemeral forage is also greatest. Areas with a low potential to produce ephemeral forage usually produce only one or two species of flowering plant. These areas often show up very well on satellite imagery such as in Figure 14b, where the yellow areas are extensive stands of bladderpod in bloom; also see Figure 19. Such areas are monotonous when compared to those producing a variety of colors.

Vegetative types or communities, levels of ephemeral forage production, potential to produce forage, and plant phenology are aspects of plants which can be monitored on satellite imagery by separating various hues, tones and textures. Through a comparison with ground truth data, plant signatures are correlated with specific colors and textures isolated on the imagery. This technique was successful using color composites produced by the principal investigator using a homemade light table and a Nikon F2 camera. Color composite imagery of the quality produced by the Goddard Space Flight Center or the IBM Corporation, Bernstein (1973), would greatly increase the amount of information a resource manager could obtain for land use management.

B. California Study Site

Boundaries of broad soil types (series) in the desert of southeastern California can be mapped on MSS band 5 of ERTS satellite imagery. Specific information concerning soil characteristics was obtained through collection of ground truth data. Ground truth also pointed out that boundaries of broad vegetative communities corresponded to the soil type boundaries identified on satellite imagery. Vegetation could not be seen on the imagery because of the extremely low percent of ground covered by plants.

This study shows that soil and vegetation can be mapped on a regional basis using satellite imagery to locate boundaries. Ground truth data is necessary to determine what lies within those boundaries. No attempt was made to test whether homogeneous areas on the imagery corresponded to areas on the ground having similar soil and vegetation characteristics. All polygons drawn on the imagery appeared to be a separate and distinct gray tone; therefore, ground truth measurements were made on all corresponding areas on the ground.

Soil and vegetation data are a primary input into the data bank provided within the BLM planning system; BLM (1969). Nearly every use made of our natural resources has an imapct on either soil or plants. Decisions made during the planning process to improve resources or control their use require a knowledge of these two basic components. On vast areas as large as the California desert, collection of resource data can be a problem, especially when agencies are required to work within the manpower constraints which have existed during the last several years. Satellite imagery can be a very important tool which the resource manager can use to fully utilize his limited people resources.

C. Oregon Study Site

Preliminary work done on the Oregon test site indicates that broad categories of vegetation can be mapped on color composite satellite imagery. It was found that photo enlargements of specific areas at an approximate scale of 1:350,000 gave better results than the 1:1,000,000 scale imagery. Boundaries of revegetation projects and areas burned by wildfire can also be determined from satellite imagery. However, this statement is based on general occular estimates over several broad areas and not on detailed ground truth data. Further work would be needed to definitely show this to be true or false. No attempt was made to test whether effects of livestock grazing could be seen on satellite imagery.

D. Alaska Test Site (Seward Peninsula)

Broad vegetative communities can be mapped on color composite satellite imagery at the 1:1,000,000 scale. Enlargements at a scale of 1:250,000 are especially useful and allow mapping to a greater detail. Boundaries of wildfire areas can also be mapped in great detail. In an area as large as Alaska where very little resource information is available, satellite imagery could be a tremendously useful tool for gathering data. However, weather in Alaska (clouds) during the short snow free period can be a very serious problem.

V. SUGGESTIONS FOR IMPROVEMENT IN THE SYSTEM

This study was designed to determine if satellite imagery could be useful to a land management agency as a data gathering tool. Results show that in theory, color composite satellite images could be useful. However, in practice, imagery such as was used in this study would only be of marginal assistance to resource managers. The reasons behind this statement have little to do with the equipment aboard the satellite which is in direct contrast to questions which existed at the beginning of the study.

Two major problems exist in the system designed to handle satellite data after it reaches the earth. These problems greatly restrict the ability of BLM to use satellite imagery. First, in order for color composite satellite imagery to be useful to resource managers, it must be in their hands within one week of the date of the satellite overpass. Imagery older than this is only of historical significance, especially to persons concerned with development of plants during a current growing season. When an area manager is required to make a decision on a request by a rancher for a license to graze cattle, he must have current resource information. If BLM is to direct tourists to the best areas to find wild flowers, they need to know what the vegetation looks like today, not two months ago. When a motorcycle club requests an area to hold a race in, BLM must know enough to keep them out of the wild flower areas.

Second, color composite imagery must be of high quality. Sensors aboard the spacecraft are capable of producing high quality data. Second generation images (bulk processed) produced by NASA have good resolution and are suitable for general observation. However, the scenes are distorted somewhat because of roll, pitch and yaw and forward motion of the spacecraft. Horizontal distance distortion on the imagery makes it very difficult to transfer resource information from satellite data to a map. When NASA produces a distortion free image (precision processed) resolution is degraded in the rectification process. This makes analysis of data more difficult. When imagery is sent by NASA to the Sioux Falls Data Center for further distribution to the users, an additional source of image degradation is introduced. Sioux Falls takes a NASA second generation product and reproduces it to make a relatively poor third generation product. If that product is a set of positive transparencies, to be made into a color composite by the user, further degradation results.

High quality second generation, fully rectified color composite images have been produced by a digital process, Bernstein (1973). This procedure can also produce enlarged images with minimal loss of resolution. For BLM's purposes, a 1:250,000 scale image is particularly useful for gathering resource information. Imagery at this scale provides accurate data for relatively small ground areas considering the great distance from the satellite sensor to the earth. The 1:250,000 image also provides a uniform base scale for all administrative units (districts). The satellite image can be used directly as a map or information taken from the image can be put on a standard 1:250,000 U.S.G.S. Quadrangle map. Information for different dates within a single growing season or for successive seasons can be easily compared when scale is constant.

VI. GLOSSARY

Aspect - Direction the surface of sloping land faces -- north, south, east or west. Also defined as the general complexion of the vegetation of an area as it appears to an observer, stated in terms of the most conspicuous plant or several plants.

Animal Unit Month (AUM) - The amount of range forage required to sustain a mature cow for one month.

Bajada - Synonomous with outwash plain. A relatively flat, even slope located at the base of a desert mountain outcrop and extending to the valley floor.

Basalt - An inorganic material of volcanic origin.

Color Additive Viewer - Equipment designed to project light through four positive transparencies in four different bands of the electromagnetic spectrum, then through a variety of combinations of blue, green and red filters. The four beams of light are then converged into a single false or simulated color image and this image is projected on a viewing screen.

Color composite - A simulated or false color image created by recombining several images of an identical area, but each representing a different band of the electromagnetic spectrum.

Density - Number of individual plants growing in a given area.

Dormant - A stage of perennial plant development reached after maturity where all visible signs of growth stop. Plants then over-winter in this stage.

Ecosystem - Living organisms and their nonliving environment inseparably related together, interacting upon each other.

ERTS Frame - One individual satellite image.

Electromagnetic Spectrum - The classification according to wavelength, of all energy that moves at the constant velocity of light in a harmonic wave pattern.

Ephemeral plant - An annual plant that grows during a specific season, such as winter or summer and may complete its entire life cycle in a short period of several weeks.

Forage - Plant material grazed by livestock.

Forage production - The amount of plant material produced during one growing season.

Forb - An herbaceous plant with colorful flowers and without woody parts. Can be perennial or annual (ephemeral).

Grass plant - An herbaceous plant with narrow linear leaves composed of a sheath and a blade, with very small inconspicuous (green) flowers. The growing point being protected in the base of the plant near the ground line.

Ground cover - The portion of the ground covered on a given area by live plants, usually expressed as a percentage.

Ground Truth Data - Measurements made on the ground of plants, soil, etc. to be used to verify items identified on aircraft or satellite imagery.

Growing Season - A period of the year when suitable temperatures and adequate precipitation combine in a favorable climate for plant growth.

Herbaceous - Fleshy plant growth; no woody structure.

High flight - Usually applied to aircraft imagery taken from altitudes within a range of 45,000 to 65,000 feet.

Homogeneous - An area identified on imagery with a continuous hue, tone and/or texture throughout.

Hue - The attribute of colors that permits them to be classified as red, yellow, blue, green, etc. Synonomous with color.

Image - A likeness of an area on the ground obtained from a camera, scanning device, or other imaging system, reproduced on film.

Inflorescence - The flowering portion of a plant.

Interpreter - A person who analyzes imagery to obtain resource data.

License - Authority to graze livestock upon the public domain for the purpose of harvesting forage.

Mosaic - A very broad vegetative category delineated on ERTS imagery which includes several plant communities intermingled together.

Natural barrier - A natural topographic feature, such as a cliff, ledge or steep slope which cannot be easily traversed on foot.

Natural resource - A feature occurring on the land which is a part of nature and has an inherent ability to restore itself, such as vegetation.

Near infrared - Wavelengths slightly longer than those of visible light, but which can be recorded on color infrared film which shifts the emulsion layers and uses the red layer to record infrared energy. Actively growing healthy plants emit energy in the near infrared wavelength region.

Occular estimates - A procedure used by BLM where resource personnel estimate features of the vegetation such as percent ground cover rather than make actual measurements. Estimates are based on frequent measurements taken to help individuals maintain accurate mental pictures of the various increments in the amount or level of plant characteristic being recorded.

Orographic lifting - Air is forced upward along mountain slopes by wind. As air rises it cools, expands and the dew point lowers. Moisture in rising air thus condenses into rain drops and precipitation results.

Outwash plain - See Bajada.

Overlay - A clear plastic material placed over imagery. Resource data on the image is transferred to the overlay with marking pens.

Pace - A means of measuring distance or systematically locating study sample points. A pace is measured each time the right foot touches the ground or two steps, approximately five to six feet.

Perennial plant - A plant whose life cycle spans more than one growing season; does not die at the end of the growing season and begin as a new plant next year from seed.

Phenology - Growth and development stages in the life cycle of a plant such as initiation of growth, first leaf stage, flowering, seed ripe, maturity, dormancy.

Plant composition - The percentage that each individual species of plant makes up out of the total community.

Plant measurements - Measurement of aspects of plants which give data about vegetative differences occurring on various ground sites. Measurements include kinds of plants in the community, percent of ground covered by plants, stage of growth (phenology), and current forage production.

Plant signature - The effect a given plant or plant community has on reflected light and the results of this pattern of light as seen in the imagery.

Playa - A prehistoric lake bed now filled with soil and dry. Soil is generally highly saline.

Polygon - A line (boundary) drawn around an irregular area.

Potential productivity - The natural inherent ability of an area to produce forage.

Public domain land - Unappropriated land left over from the original public domain administered by the Bureau of Land Management.

Range - Rangeland or land used for grazing livestock.

Range readiness - The period when forage plants have made sufficient growth so grazing will not cause plants undue harm. The point when grazing can begin.

Registration - Superimposition of several positive transparencies so they appear as one image with no overlap or distortion.

Resolution - The ability to identify specific items found on imagery or separate different items from each other.

Revegetation project - A project whereby existing vegetation is removed mechanically or chemically and replaced with a new kind of vegetation by seeding.

Scale - Scale of an aerial photograph or image is expressed as a ratio, giving the number of units of distance on the ground equivalent to one unit on the photo.

Shrub - A woody, multistemmed perennial plant, generally spherical in shape and usually not more than 10 feet tall.

Soil horizons - Distinctive layers of soil, approximately parallel to the soil surface, with characteristics produced by soil-forming processes.

Species - A category of biological classification ranking immediately below the genus comprising related organisms capable of interbreeding.

Stand - A group of similar plants growing together on an area.

Stratified - To divide an area into sub-areas with homogeneous characteristics such as one having a cover of one kind of plant or group of plants.

Texture - The grain or peculiar character of a surface which causes it to look smooth or rough.

Tone - An intermediate hue; a degree of color in the value scale.

Topography - The configuration of natural features, including surface relief.

Transect - A straight line traversed through a sample area upon which measurements are made at regular, predetermined intervals.

Tree - A single-stemmed perennial plant generally more than 10 feet tall at maturity.

Triple-Exposure (Multiple-exposure) - The technique of exposing more than one image on one single negative.

Vegetative Community (Vegetative type)- A group of plants growing on an area; the composition of species being separate and distinct from neighboring groups.

VII. BIBLIOGRAPHY

Anderson, J.H. and A.E. Belon. 1973. A new vegetation map of the western Seward Peninsula, Alaska based on ERTS-1 imagery. National Aeronautics and Space Administration. Interim Scientific Report. February. 20 pp.

Belon, A.E. 1972. A description of the photographic technique used in making reconstituted color-infrared prints. Personal Correspondence with A.E. Belon. Geophysical Institute of the University of Alaska. 1 pp.

Bernstein, R. 1973. Results of precision processing (scene correction) of ERTS-1 images using digital image processing techniques. IBM Technical Report No. FSC 73-0048. Presented at the ERTS-1 Symposium, NASA Goddard Space Flight Center, March 5-9, 1973. 8 pp.

Bowden, L.W. and C.W. Johnson. 1972. A recipe for "do-it-yourself" color composites of ERTS-1. Presented to Third Annual Conference on Remote Sensing in Arid Lands, Tucson, Arizona. November, 1972. 2 pp.

Bureau of Land Mgt. 1972. BLM Manual 7322. 11B3. Release No. 7-47. 3-20-72.

Bureau of Land Mgt. 1969. BLM Manual 1601. Release 1-547. 6-17-69.

Bureau of Land Mgt. 1968. BLM Manual 4112.15. Release No. 4-29. 10-18-68.

Carneggie, D.M. 1972. Personal conversation with D.M. Carneggie at the University of California, Berkeley.

Carneggie, D.M. 1968. Applying remote sensing technology for improving range resource inventories. Proc. Fifth Symp. on Remote Sensing of Environment. Univ. Michigan, Ann Arbor. 373-385 pp.

Dodge, N.N. 1958. Flowers of the southwestern deserts. Southwestern Monuments Assoc. Popular Series No. 4. 112 pp. Illus.

Driscoll, R.S. and R.E. Francis. 1972. Remote sensing applications in forestry -- multistage, multiband, and sequential imagery to identify and quantify non-forest vegetation resources. Rocky Mtn. For. and Rng. Expt. Sta., Forest Service, U.S.D.A., Fort Collins, Colo. Final Report to NASA. 30 Sept. 72. 49 pp.

Eastman Kodak Co. 1970. Producing slides and filmstrips. Audiovisual Data Book, S-8. Rochester, N.Y. 57 pp.

Kearney, T.H. and R.H. Peebles. 1960. Arizona Flora. Univ. of California Press, Berkeley. 1085 pp.

Krumpe, P.F. 1973. A regional approach to wildland resource distributional analysis utilizing high altitude and earth orbital imagery. Proc. American Soc. of Photogrammetry, 39th Annual Meeting, Washington, D.C. March 11-16, 1973. 336-371 pp.